An Evaluation of Fire Retardant Use

Policy Analysis
Staff Report

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MAJOR FINDINGS AND RECOMMENDATIONS

The retardant program is a large and complex system, one that is not normally viewed in its totality. It involves many staffs, both within and outside Aviation and Fire Management. The program has grown rapidly in a relatively short period. For these reasons it has been difficult to establish an optimal program. This evaluation was initiated to improve understanding of the program and to identify opportunities for improvement.

The following are the major findings and recommendations.

I. Retardant Use

Conclusions

1. The effectiveness of applied retardants is not well understood.

2. The stated objective of retardants remains as an initial attack tool in support of ground forces; however, the rationale for actual application is less clear.

3. A wide disparity among large vs. small fire retardant use exists between Regions.

Recommendation

The effectiveness of applied retardants should be established, differentiating between such things as fire conditions, vegetation, drop configuration, ground force follow up, and fire size.

II. Retardant Program as a System

Conclusions

1. The retardant system is composed of six major components: (1) retardants, (2) base operations, (3) air tankers, (4) lead planes, (5) research and development, and (6) administrative support.

2. Considerable variation in component cost exist within and among Regions.

3. An analysis of the system's components and their interelationships need strengthening.

Recommendation

Improve the efficiency and effectiveness of the retardant system by applying more rigorous analysis to the selection and location of retardants, bases, air tankers, and lead planes.

III. Research and Development

Conclusions

1. Existing retardant analytical models are not widely accepted or understood.

2. Basic knowledge regarding effectiveness of applied retardants is lacking.

3. Management and research are not in agreement on retardant system research priorities.

Recommendation

Identify, prioritize, and support research and development needs for the retardant program system.

IV. Program Management

Conclusions

1. The air tanker contract is a key element in acquiring and managing an efficient and effective air tanker fleet.

2. Air tanker efficiency and effectiveness is dependent on a host of characteristics involving the aircraft (and its tank and gate system), location, and tactical use.

3. The Forest Service role in assuring the airworthiness of air tankers and the extent of the problem is unclear.

4. Collection and management of data is disjointed and inadequate.

Recommendation

a. The air tanker contract should be used as a tool to improve the efficiency and effectiveness of air tankers. This requires a clear definition of management needs.

b. A single retardant system data base should be developed and utilized.

V. Policy and Direction

Conclusions

1. Fire management policy as stated in FSM 5100 encompasses aviation policy considering it as an activity in the suppression of wildfire.

2. Aviation policy lacks direction on how to accomplish an efficient and effective program.

3. Direction for effective application of retardants is very minimal.

Recommendation

Develop manual direction (FSM and FSH) for accomplishing an efficient and effective retardant system program. This should include planning, analysis, application, and monitoring.

An Evaluation of Fire Retardant Use

I. INTRODUCTION

Because aerially delivered fire retardants are a high cost item and attract a considerable amount of attention. On this basis, the Deputy Chief for National Forest Systems asked that the Policy Analysis Staff conduct an evaluation of retardant use.

The efficiency and effectiveness of current retardant supply and delivery operations and the policies and directions that guide those operations are examined. The intent of this report is to provide information for better understanding of the program and to identify opportunities for improvement. In most cases additional analysis and staff work will be necessary for those opportunities that appear to warrant further consideration.

The study is national in scope and provides a regional breakdown of data. Data are further broken down and discussed for specific items. Data covering the period 1977-1981 have been gathered for most activities. The study is concerned with retardant delivered by fixed-wing aircraft only.

This report is divided into five chapters: (I) introduction; (II) description and analysis of the various retardant systems; (III) discussion of research and development; (IV) review of program management; and (V) discussion of policy and direction.

In 1936 the Forest Service began efforts to develop an aerial retardant program. The objective was to "develop techniques for dropping fire retardants with sufficient accuracy and concentration to hold small fires, pending arrival of ground crews" (Wilson, 1980).

The aerial fire retardant program became operational beginning in the mid-1950's using relatively small agricultural and surplus military aircraft to drop water. Since then the program has progressed to dropping specifically designed retardants using large, modified bomber and transport aircraft combined with complex sophisticated support systems. In the 1981 fire season, the program involved the delivery of 11.9 million gallons of retardant from 46 support bases using 43 aerial tankers and 21 support aircraft. The total current annual expenditure is approximately $25 million or $2.11 per gallon of retardant dropped.

Though it is often perceived otherwise, the original objective as restated by current fire managers has not changed. Forest Service fire managers in responding to this study were in agreement that the primary purpose of retardants is as an initial attack tool for delaying the spread of a fire. This provides ground forces additional time to get into place and complete their efforts at suppressing a fire. On rare occasions retardants have been known to actually put out a small fire. While retardants are often used on large fires, where they are thought to be less effective, their major use and justification are as an initial attack tool. In both situations it was commonly agreed that the air tanker is a tool which (when used at the appropriate time and place) can efficiently and effectively supplement or support, but not replace ground fire-fighting forces.

The data presented in Table 1 compares actual retardant use with its primary objective; i.e., initial attack. Due to the form in which data are recorded by Regions, it was necessary to separate use into large fire use--Class D and larger[1] and small fire use A, B, and C fires. This appears to be an adequate division for two reasons. First, initial attack is a loosely defined term with little agreement on definition by Regions, except that all retardant use for A, B, and C fires is considered to be initial-attack application. Second, while large fires may also attack initially with retardants their small total number (1.6 percent of all fires) suggests that only a minor amount of application could be accounted for on large fire initial attack.

The data indicates that nationally 64 percent of the retardant use in terms of gallons is for initial attack while 36 percent is for large fires. Most Regions used several times more retardant for initial attack as compared to large fires use. In Regions 2, 5, and 10 large fires use exceeded initial attack use. The data above (and in Table 1) suggest that the initial attack objective is not the primary objective in some Regions. Indeed, data in Appendix N suggest that it is perhaps a secondary objective. When retardant use is viewed as the percent of fire attack, we find that 9 percent of all the large fires used retardant and only 2 percent of the small fires used retardant.

While the objective remains clear in managers' minds it is less clear from the data. If the objective is in question, perhaps, we are asking the wrong

[1]The Large Fire Report form (5100-11) records all fires 100 acres and larger.

Small vs. Large Fire Use 1/

Table 1

Region	Number of Fires								Gallons A,B,C	Gallons D,E,F,G,	Gallons All Fires
	Class A	Class B	Class C	Class D	Class E	Class F	Class G	All Fires			
1	801	214	32	4	4	2	-	1057	299,816	124,623	424,439
2	519	173	27	3	3	2	-	727	41,740	88,600	130,340
3	1811	505	81	12	7	5	1	2422	1,132,650	524,500	1,657150
4	875	177	32	9	7	3	3	1106	394,919	360,376	755,295
5	1800	408	71	21	15	11	6	2332	1,707,309	2,310,890	4,018,199
6	1369	299	23	7	2	2	0	1720	2,663,266	285,951	2,949,217
8	539	1284	450	44	12	4	0	2333	459,095	97,014	556,109
9	232	437	121	8	2	1	0	801	51,699	7,880	59,579
10	19	3	1	0	0	0	0	23	2,000	3,600	5,600
TOTAL	7965	3500	838	108	52	30	10	12503	6,752,494	3,803,434	10,555,928
Percent of Total		98.4		.9		0.7		100	64	36	100

Source: USDA Forest Service, 1982e, 1977-1981a, and 1977-1981b.

Notes: 1/ All data represents 5-year average values 1977-1981.
2/ When values differed from 5700-10 reports regional inputs were used.

question. The question is not--are retardants previously for initial attack or large fires? Rather it should be--under what fire and site situation are retardants effective?

While air tankers have proven to be a useful fire fighting tool, and both the numbers and sizes of air tankers have increased during the past two decades, Wilson reports in 1980 and Peterson in 1982 that mission effectiveness, according to reliable reports from ground firefighters, is said to have remained at about 30 percent. While this suggests very low mission effectiveness, there are two other reports which indicate a much higher mission effectiveness rate. An article in "Fire Management Notes" (Bjornsen, 1968) reports that 62 percent of the retardant missions provided definite help. A Canadian study by Hodgson and Little in 1970 stated that retardant drops were judged to be effective in 70 percent of the attacks. Therefore, it can be concluded that effectiveness ranges from 30 to 70 percent or that the wide range in data suggests that actual effectiveness is unknown. It should be noted that these investigations were very limited in scope and little effort was made to explain or differentiate effectiveness. For instance, was the retardant chemical effective and was it needed?

It is not suggested that retardant drops should be 100 percent effective, but rather that there appears to be considerable opportunity for improvement, saving, and refinement in our knowledge of just how effective retardants are. Wilson further stated that, "it is rather surprising that someone hasn't looked very critically at the cost effectiveness of the retardant and air tanker program sooner."

Conclusions (I)

1. The effectiveness of applied retardants is not well understood.

2. The stated objective of retardants remains as an initial attack tool in support of ground forces; however, the rationale for actual application is less clear.

3. A wide disparity among large vs. small fire retardant use exists between Regions.

II. RETARDANT PROGRAM AS A SYSTEM

The purpose of this chapter is to provide descriptive information and analysis about the activities which make up the aerial retardant program, in a manner which provides the manager and decisionmaker with an expanded knowledge and background from which to weigh conclusions and recommendations for improving the program.

Too often the retardant operation has been viewed only as air tankers or chemicals. Important additional elements and their costs, impacts, and interrelationships are usually overlooked.

For purposes of discussion, aerial retardant activities have been grouped into components in this chapter. When combined, these components represent what is referred to as the "retardant program system." Each component is a necessary element of this system as it now operates. (See Figure 1.)

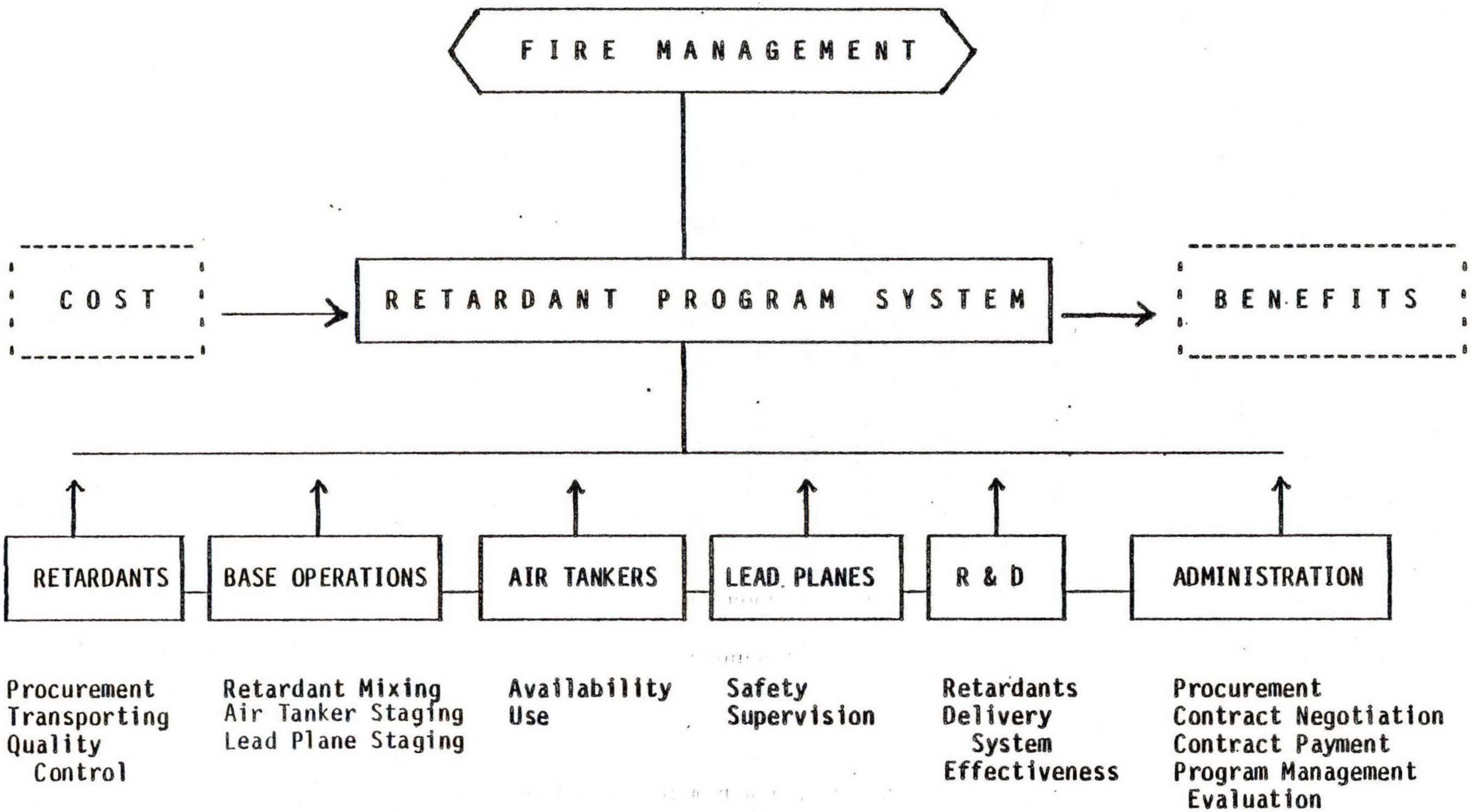
The components are:

1. Retardants
2. Base Operations
3. Air Tankers (fixed wing)
4. Lead Planes
5. Research/Development
6. Administration and Support

Cost data and information have been developed for each component of the system and are reported for the years 1977-1981. From their summation a picture of the total retardant operation and cost emerges.

RETARDANT PROGRAM SYSTEM

Figure 1



The information was obtained from a variety of sources including interviews, written requests, conversations, and published and unpublished reports. Washington, Regional, research and industry personnel were consulted. All freely provided information and insight.

1. Retardants - Retardant may be defined as "a substance that by chemical or physical action reduces or inhibits flammability of combustibles. Rate of spread of flame front is thereby slowed or retarded" (Wilson, 1980). About 50 percent of the retardants used by the Forest Service (those used at Forest Service operated bases) are supplied through GSA negotiated sole source contracts. Regions also may develop full service contracts that include delivery to the air tanker. These contracts are bid and open to any vendor who can supply the service. A small amount of plain water is also applied aerially as a retardant primarily in Region 9.

The sole source contracts are negotiated annually on the basis that products supplied by the two major producers (Monsanto Industrial Chemicals Company and Chemonics Industries Inc.) are not identical and cannot be readily interchanged at individual using locations. Sole source allows the Federal agencies to directly purchase the type of chemical retardant best suited to their locations and needs. However, the cost per gallon is usually $.10 to $.25 higher than when retardants are purchased directly from the vendor.

There has been some discussion of turning the negotiation of these contracts over to the Forest Service, but the economic consequences are not clear. Further examination and discussion is needed.

Reports supplied by the chemical industry and Federal contracts indicate that 15,840,000[2] gallons of fire retardant were sold in the United States in 1981 and that approximately 75 percent or 11,886,076 gallons were supplied to the Forest Service. Of the volume used by the Forest Service, 65 percent was supplied by the Monsanto Company, 30 percent by Chemonics Industry, and 5 percent by Omega. Retardant costs for the Forest Service in 1981 totaled $7,762,429 and averaged 65.3 cents per gallon including shipping and packing charges (see Table 2). Retardant use in 1981 was fairly representative of average use. But as is usually the case, considerable fluctuation in use occured regionally and at individual bases. Regional retardant use and cost for the past 5 years are presented in Table 3. (National use since 1959 appears in Appendix B.)

The retardants used at a given base must be selected from an approved list of eight long-term retardants provided by the Washington Office. (See Appendix D for a description of approved retardants.) Generally, only one retardant is selected and used at a given base.

Selection of a specific retardant type should be directly related to fuel types, tactics, costs, and effectiveness. A retardant value analysis model is available to assist in this effort and is discussed in Chapter III.

Many factors go into the selection of the appropriate retardant. Several are only indirectly related to the use. Some retardants can be stored after mixing;

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[2]For the purpose of discussion, all units of retardant have been converted to gallons in the report.

FY 1981 Retardant Use and Cost

Table 2

Region	Phohek 1/		Fire-Trol 2/		Omega 3/		Totals	
	Gallons Phoschek	Total Costs1/	Gallons Fire-Trol	Total Costs2/	Galons Omga	Total Costs	Gallons	Cost
1	707,756	468,534	59,750	38,957	0		767,506	507,491
2	45,048	29,822	23,300	15,192	0		68,338	45,014
3	480,021	317,774	780,118	508,637	0		1,260,139	826,411
4	1,018,638	674,338	0	0	0		1,018,638	674,338
5	5,041,577	3,337,524	8,800	58,018	0		5,940,377	3,923,542
6	0	0	1,823,693	1,189,048	637,646	351,824	2,461,339	1,540,872
8	369,729	244,761	0	0	0		369,729	244,761
TOTAL	7,662,769	$5,072,753	3,585,661	$2,337,852	637,646	$351,824	11,886,076	7,762,429
Percent 5/	65		30		5		100	

Source: Appendices C and E

Note: All price/gallon data include shipping costs

1/ Monsanto product cost = $0.662 per gallon
2/ Chemonics product cost = $0.652 per gallon
3/ Omega product cost = $0.522 per gallon
4/ Average product delivered = $0.653 per gallon
5/ These percentages will vary annually based on the demands at specific bases.
6/ Use is for Forest Service operated and cost sharing bases only.

Retardant Use and Cost 1/

Table 3

Region	Gallons Used 1977	1978	1979	1980	1981	5-year Average	% of Total	Average Cost 3/
R-1	428,754	31,412	812,333	130,612	767,506	434,123	4	283,482
R-2	290,016	238,539	112,434	193,345	68,348	180,537	2	117,891
R-3	1,820,515	559,556	2,094,826	1,833,397	1,260,139	1,513,687	13	988,438
R-4	290,935	324,967	825,026	503,240	1,018,638	592,561	5	386,942
R-5	6,582,301	4,338,280	7,510,098	7,411,760	5,940,377	6,356,563	53	4,150,836
R-6	4,070,480	1,038,340	3,217,762	1,256,727	2,461,339	2,408,927	21	1,573,029
R-8	200,839	459,865	82,588	171,417	369,729	256,887	2	167,747
R-9 2/	2,400	0	0	37,000	0	7,880	0	5,146
R-10 2/	0	10,000	0	18,000	0	5,600	0	3,657
NATIONAL TOTAL	13,686,240	7,000,959	14,655,067	11,555,498	11,886,076	11,757,765	100	

Sources: 1/ Regions 1-8 data are from Appendix C.
2/ USDA Forest Service, 1977-1981c.
3/ Computed value using an average cost/gallon of $.653 from Table 2.

others cannot. Each retardant requires its own mixing procedure and specific mixing equipment. Some retardants are easier to handle then others. Equipment corrosion caused by the chemicals has been a major concern at times. Much additional information on retardant properties and their use is contained in a publication by Charles E. Hardy in 1976.

With regard to use, two factors are key: cost and effectiveness. Cost will vary depending on the properties of the material, the vendor and contractual arrangements, and the shipping costs.

The question of effectiveness is very important. Unfortunately knowledge of effectiveness is limited to a few individuals and laboratory test results. As mentioned in Chapter I, field experience is relied upon heavily. The result is that subjective opinions form the bases for selection with limited ability to communicate or verify effectiveness of the product.

Another aspect of effectiveness is quality control. In a discussion with Norm Anderson (a former Forest Service equipment development and testing specialist), he has pointed out that recent spot checks have revealed retardant products (both before and after mixing) have not met required specifications. To address this problem a process called "Fire Retardant Lot Acceptance and Quality Assurance Program" has been initiated (Hafterson, 1983).

Still another aspect which is current on the minds of several fire managers is the opportunity to employ "short-term retardants." These substances do not contain an active chemical and rely primarily on water as the retardant agent with a thickener and coloring agent added. Consequently, unlike long-term retardants, the retarding properties disappear when the water evaporates.

The primary reason for considering short-term retardants is their cost. They generally require less mixing equipment and are considerably less expensive to purchase (approximately $.20 per gallon). While they are not as effective in all fire situations, it is estimated that in California they could be equally as effective as long-term retardants in 20 percent of the fire situations (Weaver, 1982).

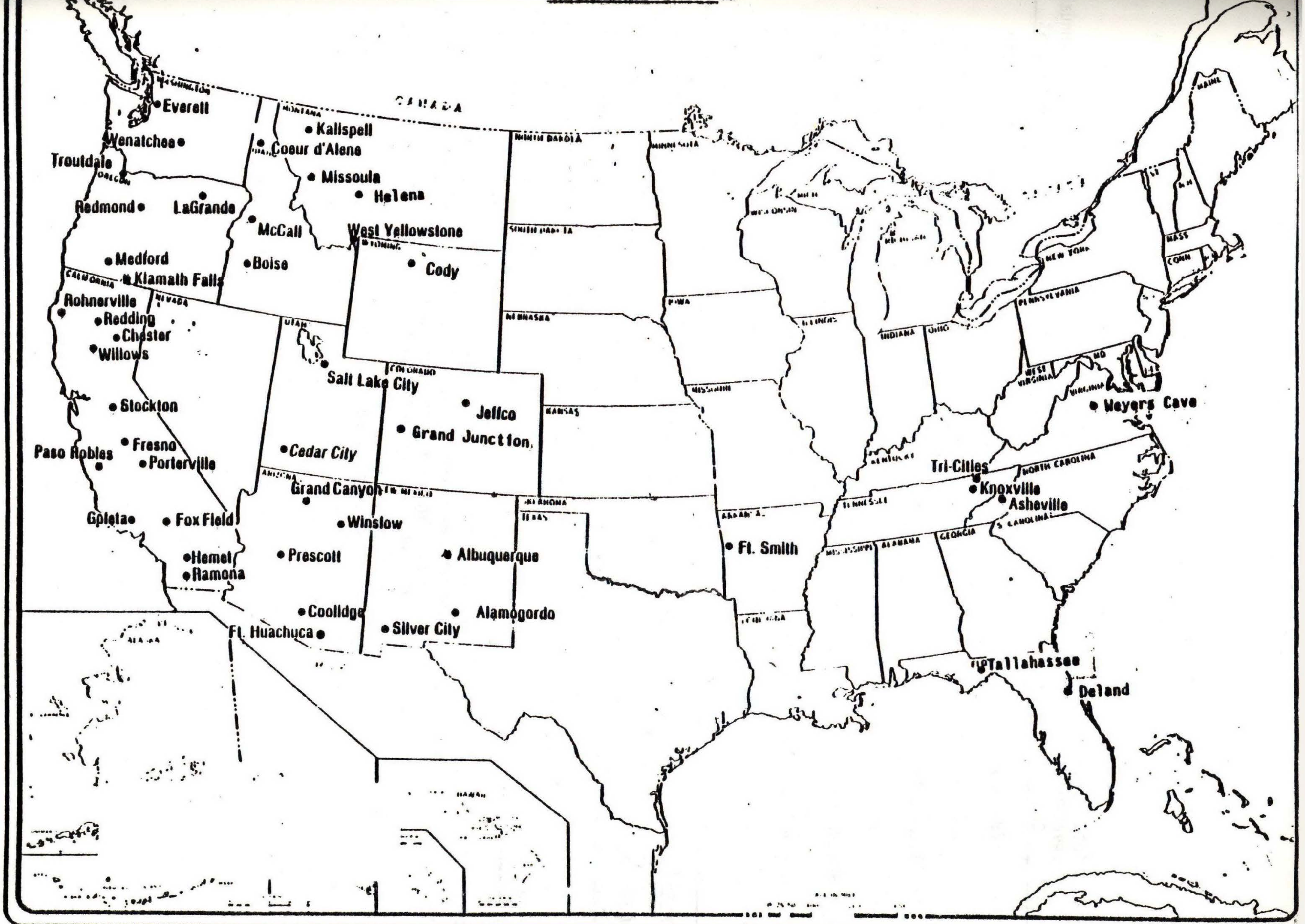
The California Department of Forestry is cooperating with the Forest Service in Region 5 to evaluate short-term retardants current plans are to expand this effort. At present there are no Forest Service approved short-term retardants.

2. Base Operations - Permanent retardant bases are located at various airports throughout the country (see Figure 2). These bases support and provide services to contracted air tankers. Forest Service facilities at the bases typically include: buildings; taxi ways; parking ramps; retardant mixing, storing, and pumping equipment; and communication facilities. A few portable bases and facilities are available, but play only a minor role. The potential for expanding their use is discussed later in this section.

Air tanker base data and costs were collected from each Region for the past 20 years and from WO budget information for investments in the years 1980, 1981, and 1982. Regional investment data, while incomplete, suggest that investments for any given year can vary considerably above or below the average values used in this report. Investments were inflated to 1981 dollars and amortized over a 15-year period to arrive at annual investment costs. A summary of regional base operational costs is provided in Table 4.

Figure 2

RETARDANT BASES 1/



1/ USDA Forest Service, 1982e.

Base Operation Costs by Region 1/

Table 4

Region 5/	Total Base Investment Cost	2/ Annual Investment Cost	Annual Maintainence Cost	Annual Operating Cost	3/ Total Annual Base Cost
1	297,418	19,828	1,876	32,716	54,420
2	288,100	19,208	5,100	16,183	40,491
3	1,630,323	108,688	13,500	706,217	828,405
4	245,104	16,240	9,787	62,513	88,540
5	3,463,300	230,888	57,000	423,400	711,288
6	1,105,200	73,680	27,800	228,200	329,680
8	584,225	38,950	7,250	76,035	122,235
TOTALS 4/	7,613,670	507,482	122,313	1,545,264	2,175,059
PERCENT OF TOTAL		23	6	71	100

Source: Appendix F

Notes:
1/ All costs are in 1981 dollars.
2/ A 15-year amortization rate was used to calculate annual investment cost.
3/ Exclusion of retardant cost, which are covered in next section.
4/ Regions 9 and 10 do not operate bases but rely on other agencies and pay on a per gallon basis for retardant.
5/ Data is for all bases that were operated for one or more years during the past 5 years.

Air tanker base operations represent a significant cost in the delivery of retardant to a fire. Nationwide their total annual cost is estimated to be \$2,175,059. Of this, \$507,482 or 23 percent represents investment costs. Maintenance accounts for \$122,313 or less than 6 percent. The primary expense is the actual operation of the facility which requires an annual allocation of \$1,545,264 or 71 percent of the annual cost. Operating costs include salaries, leases, utilities, and training.

Base operating costs can be expected to increase rapidly during the next decade as lease agreements with airports expire and new investments are incurred. Several Regions are facing lease renewal, relocation of bases, and base consolidations.

Base improvements are also needed to meet new airport restrictions and standards and to accommodate larger retardant aircraft. In one recent example involving a renewed lease agreement, lease rates for land went from \$80 per acre to \$4,500 per acre per year.

The cost to operate individual bases varies considerably. Table 5 has been constructed to express efficiency of the various bases. For comparative purposes, the data has been reduced to cost per gallon. The cost to ship the retardant to the base is a factor of location and has, therefore, been added to the base efficiency calculation.

The volume of business or the amount of retardant pumped at a given base greatly influences the base efficiency. It should be recognized that a high cost per gallon or low efficiency may be justified depending on the options available for

Base Efficiency 1/

Table 5

	5-year Average Gallons	Annual Base Cost	Base Cost/Gallon	Retardant Shipping Cost/Gallon 5/	Total Base 6/ Cost/Gallon
R-1					
Missoula	200,176	7,628	.038	.051	.089
Coeur d'Alene	88,730	10,495	.118	.029	.147
Helena	39,701	12,765	.322	.060	* .382
Kalispell	66,939	12,503	.187	.057	.244
W. Yellowstone	38,577	11,029	.286	.057	* .343
Region	434,123	54,420	.125	.049 4/	.174
R-2					
Jeffco	49,381	29,917	.606	.041	*** .647
Cody	35,432	3,494	.099	.121	.220
Region	84,813	33,411	.185	.074	.259
R-3					
Winslow	248,958	95,490	.384	.036	.420
Grand Canyon	163,790	127,467	.778	.046	*** .824
Albuquerque	67,759	162,313	2.395	.059	*** 2.454
Alamogordo	75,455	91,966	1.218	.039	*** 1.257
Libby	98,211	88,500	.901	.033	** .934
Prescott	211,107	117,461	.556	.023	** .579
Silver City	142,752	112,680	.789	.031	** .820
Coolidge	505,654	92,528	.183	.015	.198
Region	1,513,686	888,405	.587	.031	** .618
R-4					
Boise	295,477	48,020	.163	.046	* .209
McCall	125,520	20,493	.163	.041	.204
Salt Lake City	132,483	10,000	.075	.029	.104
Region	553,480	78,513	.142	.041	.183
R-5					
Chester	349,772	56,666	.162	.026	.188
Fox	621,193	128,000	.206	.005	.211
Fresno 1/	486,164	93,000	.191	.014	.205
Goleta	258,832	51,834	.200	.005	.205
Hemet 1/	1,408,597	73,334	.052	.007	.059
Porterville 1/	482,516	72,334	.150	.012	.162
Ramona 1/	727,147	51,286	.071	.008	.079
Redding 1/	660,855	71,800	.109	.023	.132
Willows	147,165	14,834	.101	.023	.124
Region	5,142,241 1/	613,088	.119 4/	.012 4/	.131

Base Efficiency

Table 5 (Continued)

5-year Average

	Gallons	Annual Base Cost	Base Cost/gallon	Retardant Shipping Cost/gallon	Total Base Cost/gallon
R-6					
Wenatchee	397,087	75,734	.191	.020	.211
LaGrande	294,192	40,334	.137	.023	.160
Redmond	464,601	32,066	.069	.042	.111
Everett	91,000	22,866	.251	.032	.283
Medford	557,578	61,666	.111	.068	.179
Klamath Falls	484,081	20,780	.043	.062	.105
Troutdate	120,388	76,234	.633	.048	* .681
Region	2,408,927	329,680	.137	.046	.183
R-8					
Asheville	54,739	16,166	.295	.069	.364
Tallahassee	9,873	4,750	.481	.066	** .547
Deland	30,357	12,588	.415	.072	** .487
Weyers Cave	4,129	5,185	1.256	.061	*** 1.317
Fort Smith	39,792	21,000	.528	.036	** .564
Knoxville	66,014	36,086	.547	.066	** .613
Tri-Cities	51,983	26,460	.509	.069	** .578
Region	256,887	122,235	.476	.063	** .539
National	10,394,157	2,119,752	.204	.028	.232

Source: Appendix C and F

Notes:
1/ Base operated with a cooperator cost inlude only FS cost.
2/ Based Closed.
3/ Regions 9 and 10 rely on cooperators for bases and pay only for retardants.
4/ Weighted average.
5/ Rates were calculated using actual shipping records.
6/ A relatively high cost base when viewed regionally is indicated by **, nationally by *, both regionally and nationally by ***.

fire suppression in proximity to a given base. (On the other hand, a low cost per gallon or implied high efficiency may reflect an over zealous use policy.)

Using the data presented in Table 5, an exercise was conducted to identify Regions and bases where actual efficiency might be improved. To identify high cost base operation, three comparisons were made. First, those bases within a Region that exceeded the regional average cost per gallon by 50 percent (*). Second, those Regions and bases exceeded the national average ($.232 per gallon) by 50 percent (**). And third, bases that exceeded both regional and national averages (***).

Some possible alternatives to consider for reducing cost might be to: close some low-volume bases, examine the appropriate use at all bases, reduce shipping costs by purchasing from a closer vendor, and consider portable bases for replacing some low-volume bases.

Both the chemical and air tanker industries have expressed an interest in providing portable facilities. The Monsanto Company currently has portable facilities that can be transported and made operational at any location within 24 hours (Petersen, 1982a). Air tanker companies have expressed an interest in providing portable units that could be transported in an air tanker. Also, the Forest Service currently has portable facilities, but to date they have not been widely used.

3. <u>Air Tankers</u> - Air tankers are fixed-wing aircraft that have been modified from their original design purposes to house various tank configurations with one or more gates (or compartments) for aerially dropping fire retardants.

These contract aircraft are the primary means for delivering fire retardant. The volume of retardants delivered by air tankers represents about 98 percent of the total sold in the United States in 1981 (Peterson, 1982a). The remaining 2 percent was delivered by helicopter and ground tankers.

The first regular operational flight with air tankers began on September 1, 1954, using a single engine modified TBM aircraft in southern California. During the remainder of the 1950's, small capacity air tankers dominated the scene; during the 1960's, larger capacity air tankers began to dominate. This trend to larger capacity air tankers has continued in Forest Service contracts as shown in the 1978-1981 data base provided in Table 6.

The actual number of air tankers has been reduced from a high of 48 in 1979 to a low of 43 in 1981. However, due to the general increase in individual aircraft capacity, overall capacity has remained fairly constant. While the trend has slowed, one company is currently making efforts to develop a larger air tanker (4,000 to 5,000 gallon capacity) with its own support facilities. However, the Director of Aviation and Fire Management and the Air Tanker Screening Board have taken a position of nonsupport of this effort.

Forest Service Regions have traditionally estimated the number of air tankers needed based on the 1972 Fire Planning Process (USDA Forest Service, 1972), past experience, and funds available. It is generally recognized that the 1972 Fire Planning Process over allocated protection resources in most areas. Recently, a number of analytical tools have been developed to assist fire managers in

Air Tankers Contracted and Capacity

Table 6

Year		Number of Air Tankers	Capacity (Gallons)	Total Capacity
1978		0	1050	0
		4	1200	4800
		9	1800	16,200
		16	2000	32,000
		0	2200	0
		3	2300	6900
		13	2450	31,850
		1	3000	3,000
	Total	46		94,750
1979		2	1050	2,100
		3	1200	3,600
		5	1800	9,000
		17	2000	34,000
		1	2200	2,200
		2	2300	4,600
		17	2450	41,650
		1	3000	3,000
	Total	48		100,150
1980		2	1050	2,100
		4	1200	4,800
		4	1800	7,200
		16	2000	32,000
		1	2200	2,200
		2	2300	4,600
		17	2450	41,650
		1	3000	3,000
	Total	47		97,550
1981		1	1050	1,050
		4	1200	4,800
		1	1800	1,800
		17	2000	34,000
		1	2200	2,200
		0	2300	0
		13	2450	31,850
		7	3000	21,000
	Total	43		96,700

Source: USDA Forest Service, 1978-1981

determining the best mix of resources required to suppress fires and also improve the selection of air tankers and base locations. While a few Regions are making use of these tools, there is a lack of consistency and uniformity in their application and in direction for determining the number, type, and capacity of air tankers needed.

In 1979, the Forest Service was requested by the Senate to display the implication of alternative Fire Management budget levels. In response to the request, the Policy Analysis Staff and the Aviation and Fire Management Staff developed a process for displaying and comparing alternative budget levels for a given forest (USDA Forest Service, 1979a). The Aviation and Fire Management Staff has further developed the 1979 process and it is now referred to as "The National Fire Management Analysis System." The process is explained in FSH 1909.19. This tool is capable of evaluating alternative mixes of suppression resources needed to accomplish goals and objectives in forest land management plans. To a limited extent, the process gives consideration to the number of air tankers needed.

While the "National Fire Management Analysis System" may be used to help determine the number of air tankers required, it is not a tool which can stand alone. It must be used in conjunction with other procedures which deal more specifically with analyzing air tanker needs such as: locations, capacity, and type. Tactics, individual air tanker capabilities, and costs are also important factors which must be considered. A number of tools have been developed which attempt to address these factors. They are discussed in Chapter III.

The Forest Service has also developed a back-up air tanker system using military aircraft. Its designated purpose is to provide additional air tanker capacity during extreme emergencies when conditions are beyond the capacities of the contract air tankers and when loss of life and property may be encountered. This back-up system is called the Modular Airborne Fire Fighting System (MAFFS). The system was designed for the Forest Service by the FMC Corporation to be used in C-130 aircraft. Military aircraft are supplied and crewed by the National Guard and the Air Force Reserve.

The MAFFS aircraft are used on a limited basis. In the past 5 years, they were used by the Forest Service only in 1979 and 1980. However, they were used on international assignments in Australia and the Mediterranean region this past summer.

The military does not charge the Forest Service all costs generated in the program and their actual costs are unavailable. Forest Service MAFFS costs are shown for 1978-1981 in Table 7.

Table 7

MAFFS Cost

	1978	1979	1980	1981
Training and System Maintenance	$55,000	$55,000	$86,000	$58,000
Flight Charges	0	323,000	90,000	0
TOTAL	$55,000	$378,000	$176,000	$58,000
4-YEAR AVERAGE COST				$167,000

Additional air tanker capability is also available to the Forest Service through cooperating agency agreements.

Current contracting procedures provide a fixed hourly flight rate calculated on the contracted aircraft's capacity. At the operator's discretion, a larger capacity aircraft might be supplied. The hourly flight rate is intended to cover the cost of fuel and maintenance related to use. Daily availability rates are arrived at through competitive bidding based on required aircraft capabilities and a mandatory availability period. Pre- and post-season extension rates are also used in determining the successful bidder. A number of different contracting approaches have been tried over the years. Contracting will be further discussed in Chapter IV.

Based on the 1978-1981 data, total contract costs for air tankers (daily availability and flight costs) ranged from a low of \$7.8 million in 1978 to a high of \$10.7 million in 1979. (This data corresponds well with the Fire Activity Index in Appendix A for those years.) The data are displayed in Table 8 and are separated into daily availability costs and flight costs.[3] The average cost for air tankers during the 4-year period is \$9.8 million annually. Daily availability costs accounted for 39 percent of the total cost and 61 percent were for flight operation.

4. Lead Planes - Lead planes are small aircraft used to provide close supervision of air tankers as they drop retardant on fires. These lead aircraft are operated by Forest Service pilots who are either qualified as, or accompanied by, an Air Tanker Boss. They assist the air tankers in performing their drop missions by giving drop instructions, clearing the area of other

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[3]The air tanker cost data used in this report are for Forest Service contract aircraft and Forest Service joint facility aircraft (i.e., the Forest Service cost of aircraft shared with another Agency).

Air Tankers Costs

Table 8

Year	Daily Availability	Flight Costs	Total Costs (or Total Usage
Actual Dollars			
1978	3,374,836	2,510,183	5,885,019
1979	2,924,795	5,558,706	8,483,501
1980	3,052,369	5,831,179	8,883,548
1981	3,565,226	7,061,788	10,627,014
Constant 1981 Dollars			
1978	4,480,664	3,332,691	7,813,355
1979	3,678,987	6,992,083	10,671,070
1980	3,443,557	6,578,496	10,022,053
1981	3,565,226	7,061,788	10,627,014
Average	3,792,109 (39%)	5,991,265 (61%)	9,783,373
	Days 1/	Hours	
1978	6,646	3,171	
1979	5,229	6,302	
1980	5,485	5,860	
1981	4,713	5,067	

Source: USDA Forest Service, 1983a.

Note: 1/ Mandated days only are included, pre- and post days are not.

traffic notifying ground personnel, and making preliminary passes to test conditions over the drop area. (In addition, small aircraft are sometimes used to provide recognizance and to help coordinate ground activities. They are referred to as air attack. Their function is not normally considered a part of the retardant operation and therefore, have not been included in this report.)

The Forest Service operated 13 lead plane aircraft in 1975, of which 12 were Agency owned. Nine of those aircraft were acquired from military surplus at no cost to the Agency (some refinishing was necessary). In 1977, the Forest Service increased its lead plane fleet to 21 aircraft--9 were Agency owned and 12 were leased. In 1981, the lead plane fleet consisted of 20 aircraft--17 were owned by the Forest Service and 3 leased (see Table 9). (The above figures differ from regional data presented in Appendix H. The discrepancy is primarly due to a difference in definition).

Initially the fleet was composed of several aircraft types most of which were surplus military aircraft. In 1977, a decision was made to purchase new aircraft, all of a uniform type (USDA Forest Service, 1977). The Beechcraft Baron 58P was selected. In general, aviation and fire managers interviewed have expressed satisfaction with the new fleet and the lead plane program. Lead planes are thought to have improved air tanker mission effectiveness, improved coordination, and reduced accidents in multiaircraft operations.

However, some concerns have been expressed by aviation personnel with the newly purchased Beechcraft Baron 58P aircraft. Inflight deicing equipment has not performed as anticipated, thus, restricting operations under normal and above

Lead Planes in Service

Table 9

	Aircraft Type	1975	1976	1977	1978	1979	1980	1981
FS Owned	BE T34 1/	3						
	C 310 1/	6	6	6	3	1		
	BE C-55 2/	3	3	3	3	3	2	2
	BE 58P 3/				4	8	11	15
Sub Total		12	9	9	10	12	13	17
Leased	C 310			2	5	4	3	2
	BE B-55	1	2	4	1	1		
	BE E 55		2	2				
	BE 58		1	1				
	BE 58 TC			2	4	3	3	1
	BE 58 P			1	2	2	1	
Sub Total		1	5	12	12	10	7	3
Total Fleet		13	14	21	22	22	20	20

Source: USDA Forest Service, 1982b

Notes:
1/ Military Surplus -- no cost to FS.
2/ Purchased in 1967 at a cost of $74,010 each
3/ Purchased four per year beginning in 1978: first year $248,259 each; second $278,967 each; third $310,045 each; fourth $358,050 each; One aircraft was destroyed in a 1981 crash and not replaced.

normal icing conditions. This has resulted in a reduction of some planned use. Engine life to date has not met factory specifications for normal replacement time. The engine is averaging 15 to 20 percent less time than the factory specified for major overhaul. If this continues an increase in operating cost will result.

The cost of operating lead plane aircraft has increased significantly since 1975. This is due primarily to increased use of nonamoritized aircraft (i.e., leased and purchased aircraft as opposed to military surplus).

A few managers have stated that the Forest Service could have purchased a smaller and less expensive, perhaps more versatile, aircraft to perform the job. The 58P has limited short-field capabilities, thus restricting its use to medium or large surfaced airport runways. However, the 58P's size and equipment allows it to carry four or five passengers for administrative use when not in use on lead plane missions. The greater the use, the more opportunity exist to reduce the fixed costs of the aircraft on a per-hour basis.

Lead plane hours and costs for the past 5 years were obtained from the Regions, individual use reports, and WCF documents (see Appendix H). A national summary is presented in Table 10. It displays lead plane costs and hours flown.

Annual Lead Plane Use and Cost

Table 10

Fiscal Year	Total No. Aircraft	Total Hours Flown 1/	Lead Plane Hours Flown	Total Cost Lead Plane Hours Only	Cost 1981 2/ dollars	Cost/Hour 2/ Lead Plane Missions
1975	13	5,969	1,333	$ 93,310	148,276	111
1977	21	6,249	1,557	276,630	390,665	250
1978	22	6,543	811	143,920	191,078	236
1979	22	8,332	1,709	301,680	379,472	222
1980	20	8,379	1,745	353,885	399,238	229
1981	20	7,260	1,625	423,435	423,435	261
5-Year Avg.	21	7,353	1,489		356,778	240

Source: USDA Forest Service, 1976 and 1982b.

Note: 1/Total hours flown are included only to show actual aircraft use in comparison to total use.

2/Implicit Price Deflator applied. (Council of Economic Advisors, 1983.)

The Forest Service in 1981 operated 20 lead planes at an average cost of $261 per hour (Table 10).[4] For the years 1977-1981, average use was 71 hours of lead plane work and averaged 350.12 hours for all missions.

In constant dollars, lead planes reached their lowest average use rate for the 5-year period in 1979 at $222 per hour. At that time, 45 percent of the fleet was leased and 55 percent owned. This arrangement permitted excess capacity to be terminated and the cost to be reduced when use was low. (It should be noted also that the cost of leasing decreased when the Forest Service began to

[4]Only costs directly related to lead plane missions and management have been used in developing lead plane cost for this report. However, it should be recognized that without the administrative use of these aircraft, (including other fire use) the cost to A&FM for lead plane use would be considerably higher.

purchase additional aircraft.) Since 1979 the cost per hour has risen 18 percent in constant dollars and the proportion of owned aircraft has increased from 55 percent to 85 percent.

Table 11 provides several comparisons of lead plane use and efficiency. Data are presented for each Region and nationally, also 1981 is contrasted with the most recent 5 years of data.

Nationally, use has remained fairly constant. A small decrease in total aircraft use occurred in 1981 accompanied by a small increase in lead plane use. However, the cost per hour in 1981 represents an increase of 11 over the average cost for the period.

Regionally, R-8 has the highest cost per hour, R-6 has experienced the greatest increase in cost, R-1 has the lowest use per aircraft, and the largest percentage of use attributed to lead plane activities, while R-2 has the lowest. High costs and/or large increases can be attributed to several factors: the number of total hours flown per aircraft, type of aircraft ownership, maintenance costs, and, in some instances, the accounting process used.

5. Research and Development - This component is composed of Forest Service research and development technology for aerial retardant systems. Private industry research and development costs are not included, but can be assumed to be reflected in the cost of fire retardants, air tankers, and other equipment.

It could be argued that research and development activities are not a component of the retardant system (the same could be said of the administration and support component that follows). However, research and development have played

Regional Lead Plane Efficiency

Table 11

Region	# of Aircraft		Total Hrs. Flown		Hr./ Aircraft		Lead Plane Use Hrs.		Percent LP		Cost/ Hr.		
	5-Yr. Avg.	1981	5-Yr. Avg.	1981	5-Yr. Avg.	1981	5-Yr. Avg.	1981	5-Yr. Avg.	1981	5-Yr. Avg.	1981	% In-crease
1	2.4	2	431	419	179	210	307	274	71	65	198	252	27
2	2.0	2	722	569	361	285	54	93	7	16	214	281	31
3	3.2	4	594	956	186	239	236	308	40	32	188	207	10
4	2.2	2	1,192	962	541	481	96	184	8	19	251	266	6
5	6.0	6	2,082	2,174	347	362	391	219	19	10	192	225	17
6	5.8	5	1,536	1,321	265	264	312	386	20	29	178	262	47
8	2.0	2	393	430	196	215	88	133	22	31	307	433	41
9 1/	--	2	--	429	--	215	--	28	--	7	--	271	--
10 2/	--	--	--	--	--	--	--	--	--	--	--	--	--
National	25.6	25	7,375	7,260	297	290	1,512	1,625	21	22	236	261	11

Source: Appendix H

Notes: 1/ Region 9's data is for 1981, the only year during the period when lead plane use occurred.
2/ Region 10 had no lead planes during the period.

a significant role in shaping this relatively high technical program as we know it today. Its inclusion here is to give emphasis to that point and to suggest that a program of its magnitude and cost should be examining and improving its technology.

Annual Forest Service research and development costs for year 1977-1981 averaged approximately $394,400 (George, 1982a). This represents less than 2 percent of the Forest Service annual aerial retardant systems cost.

The $394,400 given above are for the Northern Forest Fire Laboratory (NFFL) where most of the retardant and airtanker research and development has occurred in recent years. The figure does not include the various model-building efforts discussed in Chapter III, but does include the development of the air tanker guides. Perhaps of even greater significance is the projected budget for retardant related research at the NFFL. It is expected to decline to $218,000 by FY 1984 with no planned additional efforts at other locations.

6. Administration and Support - This component represents those activities necessary to administer and support the fire retardant program. As with any program of this magnitude, a considerable amount of effort goes on behind the scene and is often not recognized as part of the program. But these activities are necessary and represent a real cost to the program. Many of the administrative activities are sometimes referred to as overhead expenses. They include such things as contracting services, inspection activities, providing office space, management, and supervision. Also, a host of support activities take place such as providing and maintaining communication equipment for the

contracted aircraft, training of personnel, special studies, and inquiries for information.

The above is not a complete list of administrative and support activities, but is intended to provide a sample. It is important to recognize that they are necessary functions and must be paid for.

Cost of this component has not been identified in the same manner that was used in the other components. This was considered to be beyond the scope of this study. Instead, in collaboration with Aviation and Fire Management and the Program Development and Budget Staffs, a percentage value was assigned to this component. The percentage used is 17 percent. It is considered to be conservative. This percentage was applied to the program cost of the other fire retardant system components and the result was added to the total system cost. During the average year this represents $3.5 million.

7. Summary of Retardant System Costs - In FY 1981 the USDA Forest Service was appropriated $179,259,000 for presuppression and $99,656,000 for suppression costs for a total outlay of $271,112,000. Aerial retardant system costs in FY 1981 were $25,043,000 or 9 percent of the total cost. Approximately 11,900,000 gallons of retardant were delivered to fires by air tankers at an average cost of $2.11 per gallon. Fire activity in FY 1981 was about average.

Retardant system costs vary from year to year depending on fire severity (i.e., fuel and weather conditions) and resulting fire suppression activity. (See Table 12). For the period 1977-1981 a low of $17.7 million was expended in 1978 and a high of $26.4 million in 1979. Most of the $8.7 million variation

Summary of Retardant Program Systems Cost 1/

(Units are in Thousands)

Table 12

System	Low Use 2/ Year (1978)	High Use 2/ Year (1979)	Median 2/ Year (1981)	Average Use	Average $/Gallon	Per-cent
Retardant	4,572	9,570	7,762	7,677	.65	.32
Base Operations	2,175	2,175	2,175	2,175	.19	.19
Air Tankers	7,813	10,022	10,627	9,783	.83	.41
Leadplanes	191	379	423	357	.03	.01
Research and Development 3/	400	400	400	400	.03	.01
Subtotal	15,151	22,546	21,387	20,392		
Administration and Support 4/	2,576	3,833	3,656	3,467	.30	.16
Total Cost	17,727	26,379	25,043	23,859		
Gallons	7,001	14,655	11,886	11,757		
Cost/Gallon	2.53	1.80	2.11	2.03		

Notes: 1/ All data are adjusted to 1981 constant dollars.
2/ Low, median, and high-use years are based on volume of retardant used.
3/ Only partial accounting for cost.
4/ Estimate 17 percent for administration and additional support cost.

in expenditures is accounted for in the volume of retardant used and the air tanker flight hours.

Cost per gallon ranges from \$2.53 in a low-use year to \$1.80 in a high-use year. The reason the cost per gallon is higher during a low-use year is because the fixed costs (i.e., those incurred even if no retardant was used) must be divided by fewer gallons to arrive at the cost per gallon.

For an average year, the cost per gallon is \$2.03. Examining each component's portion of the total system cost reveals that on the average: retardants account for \$.65, on the per gallon basis, or 32 percent; base operation \$.19, or 9 percent; air tankers, \$.83 or 41 percent; lead planes, \$.03 or 1 percent; research and development, \$.03 or 1 percent; and administration and support, \$.30 or 16 percent.

Conclusions (II)

1. Retardant related discussions tend not to be viewed in a holistic context.

2. Retardants represents approximately one-third of the total system cost and their selection and procurement warrant further examination.

3. The cost to operate retardant bases vary considerably between bases and Regions.

4. Total air tanker capacity has remained stable for the past 5 years with slightly fewer and larger aircraft.

5. A sound analysis of retardant system needs has not been produced.

6. Lead plane use and cost fluctuate considerably between Regions.

7. Future retardant related research funding is expected to decline.

8. Administration is a significant cost component of the Retardant Program System.

III. RESEARCH AND DEVELOPMENT

Introduction

Early research and development work concentrated on developing the technology for designing, delivering, and applying retardants. More recently emphasis has been on improving the analytical capability for supporting decisionmaking within the retardant program system. These efforts have build on knowledge obtained through earlier research and experience. They involve a modeling approach to the system and are application oriented. This chapter reviews the modeling efforts, poses some knowledge gaps, and offers suggestions for future consideration. The existing items discussed here are not entirely products from Research, nor are they a complete listing. But rather, they are products that appear to be controversial and or warratn some explanation. In reviewing this report the Forest Fire and Atmospheric Sciences Research Staff of the Forest Service provided some additional thoughts on research needs. They appear in Appendix O.

1. Air Tanker Performance Guide - Performance guides were developed by the Intermountain Forest and Range Experiment Station (USDA Forest Service, 1979b). They are a tool which helps to identify the best air tanker performance in terms of drop sequence and line building for individual fuel situations. Given this information, a fire manager may determine the appropriate air tanker for a given set of fire conditions and how best to utilize a specific air tanker.

The guides have been completed for 90 percent of the retardant aircraft. However, for several reasons they are not being utilized to their full capacity.

For a few aircraft, guides are no longer current due to contract changes or consistent operation of the aircraft at less than design capacity.

Broader understanding of how to use the guides would increase their use effectiveness. An area where the guides have not been adequately utilized is in fire planning. They could, for example, be used in the air tanker selection process, to systematically relate the size and type of delivery system with the anticipated suppression situation. Table 13 in Chapter IV was developed to help illustrate this point.

2. Deployment Models - At least three complete and well documented computer models exist for providing information on air tanker needs. They are: DEPLOY*TANKER, FOCUS (SMOKER 2 module), and AIRPRO.

The model DEPLOY*TANKER was developed by the Management Sciences Staff at the Pacific Southwest Forest and Range Experiment Station (PSW) and has been used in Region 5 (Hirsch and Schwarzbart, 1980). Its principal purpose is to investigate the effects, on a regional basis, of additions, deletions, changes in type, and location of air tankers. The model operates on historical fire occurrence data and a set of assumptions regarding retardant travel time and quantity requirements. The model generates very limited cost data. Emphasis is on analyzing alternative aircraft types and basing strategies given the retardant requirements. In Region 5, the 1972 fire plan is the basis for establishing retardant requirements.

The FOCUS (USDA Forest Service, 1977b) model is a fire simulation approach also developed by PSW, but at their Riverside Fire Laboratory. This model evaluates

the effect of all suppression activities including air tankers. The program is designed to simulate the activities on a single forest basis, and therefore, does not provide an overall regional view of needs. Considerable detailed output is produced including variable, fixed, and investment costs. However, considerable input data is also required which makes its use often impractical on forests. Region 6 is currently using FOCUS to examine the effect of varying gallons delivered within a given time.

Both the DEPLOY*TANKER and FOCUS models provide information for increasing the efficiency of air tanker operations, they do not address the question of effectiveness. (See Appendix I for a more detailed discussion of these two models.)

A third model, AIRPRO, was developed by the Canadian Forestry Service (Simard, 1979) and tested in two provinces. It is the most comprehensive of the air tanker models and is reported to have the following potential uses: (1) to determine air tanker productivity and effectiveness; (2) to examine the response of an air tanker system to changes in its operating environment; (3) to compare individual resources and tactics and identify conditions under which each is superior; (4) to identify conditions under which air tanker resources should or should not be dispatched; and (5) to examine the temporal and spatial variability of air tanker operations.

This model incorporates most of the air tanker information contained in other models plus it provides much additional significant information. However, like most comprehensive models the task of assembling the data for AIRPRO is

horrendous. Simard estimated that it takes approximately $1^{1/2}$ years to complete data collection and run the model for a province: a great undertaking, but reported to have been well worth the effort.

3. Retardant Value Analysis - Policy (FSM 5162.03) states that "the National Director of Aviation and Fire Management in the Washington Office approves chemicals for operation use by the Forest Service, and the Assistant Director of Aviation and Fire Management, BIFC (now located in the WO) has the responsibility for administering the fire chemical and test program." Policy further states that Regions are responsible for value analyses of fire retardants used at fixed location aerial retardant bases and that a value analysis should be accomplished when there is a significant change in price structure, newly approved retardants, new or different performance requirements, need for new contracting, or need for changing retardant base equipment including aircraft.

The fire retardant value analysis model developed by Anderson and Pickett in 1981 is a systematic way of analyzing and determining the "best" retardant to meet specific needs at the lowest total cost for a particular air tanker base operation.

It utilizes laboratory research findings and operational experience and provides a systematic alternative to rely solely on individual judgement.

Instructions for performing the analysis and report are contained in a 24-page booklet entitled, "Fire Retardant Value Analysis Guide" (Anderson and Pickett, 1981) published in January 1981 by the Forest Service.

The value analysis model test how well a set of specific objectives are met for a particular air tanker base operation. The sum of the derived values for each objective provides a basis for determining the "best" retardant. This sum is suppressed as a ratio of performance to cost for meeting the objectives. Six basic objectives are tested: (1) effectiveness, (2) health and safety; (3) environmental impacts, (4) aerial safety, (5) mixing, and (6) storage. The model provides for the inclusion and consideration of additional objectives.

Laboratory research conducted by the Forest Service is the primary basis for analyzing the basic objectives. Product information and operation experience provides the basis for considering the other objectives.

The model places emphasis on line building by incorporating it into the analytic process. Other strategies may be considered, but must be entered by the user. As a result, according to verifications provided at a recent A&FM Director's meeting other strategies are not generally considered. Effectiveness of line building is impacted by the type of aircraft and tanking system used, however, a proper analysis using air tanker guides as an input is generally not done.

The model's validity has been questioned by both industry representatives and some fire managers. However, there seems to be general agreement that a formal assessment process is needed. The following list of advantages and disadvantages attempts to identify the strengths and weaknesses of the value analysis model.

Advantages

A. The process provides for a formal and uniform means of selecting the "best" retardant for a particular air tanker base.

B. The process is based on known laboratory research and operational experience and can be replicated.

C. Cost and performance are considered.

D. The process provides fire managers a means of documenting and verifying decisions about retardants.

Disadvantages

A. The process is dependent on laboratory research and historical trends for retardant effectiveness and has not been verified by field evaluations under actual fire conditions.

B. Alternative tactical uses other than line building generally are not used.

4. Effectiveness of Applied Retardants - Air tanker retardant effectiveness has been a question of concern to fire managers and researchers since introduction of the air tanker. About 244 million gallons of retardants have been dropped from air tankers in Canada and the United States between 1959 and 1979, but there has been little effort to objectively evaluate on-the-ground results. Limited and informal efforts have been carried out to determine mission effectiveness as discussed in previous sections. These efforts have produced few conclusions. Most fire managers interviewed indicated a need for some type of formal retardant mission effectiveness study. A meaningful study should distinguish between drop effectiveness, retardant effectiveness, and fire conditions. It should be noted that the effectiveness of the retardant material is not the issue. This has been well established by research prior to production. It is the application of retardants that is in question.

The Northern Forest Fire Laboratory has proposed mission effectiveness studies on several occasions since 1976. In principal, these studies have been agreed to by the WO's, A&FM and FFASR (Forest Fire and Atmosphere Science Research) Staffs and the Intermountain Station (Chandler and DeBruen, 1976). However, no study has been initiated due to disagreement over funding and project scope.

The two most significant cost components are the retardant and the air tanker flight costs. For 1981 these two costs totalled $14,823,395. Both are variable costs and relate directly to mission effectiveness. The effectiveness of delivered retardants may be enhanced by: (1) improving information relating the amounts and types of retardant needed to retard or modify fire spread under given fuel, weather, and fire behavior conditions; (2) developing techniques or methods to improve accuracy in placing drops; (3) using guidelines relating retardant distributions with aircraft tank and gating system parameters and conditions of release (height, speed, etc.); and (4) improving skills and knowledge of personnel involved in retardant application (air tanker pilot, lead plane, air attack, and ground personnel).

Discussion with fire managers suggest that most ineffective use of retardants occurs on large project fires. In part this thought to result from external pressures to use retardants as a visual means for taking action against a crisis situation. Whatever the causes of ineffectiveness, the consequences are not evaluated or monitored in any systematic manner at present.

5. Knowledge Gaps - Research and development investments in recent years have become a concern of many people associated with the fire retardant program

including industry, researchers, and fire managers. Three areas most often mentioned all relate to effectiveness: (1) delivery effectiveness, (2) retardant requirements, and (3) air tanker configuration.

Specifically the following concerns are voiced. First, research projects for retardant delivery effectiveness using laboratory test fires and test drops over airports and flat surfaces have not been validated by "operation mission effectiveness" studies. Because these types of evaluations have not been carried out, some persons question the usefulness of laboratory research when it is applied in various analytical tools and models; e.g., "retardant value analysis." Mission effectiveness evaluations should include assessment of aircraft effectiveness in dropping the load and appraisal what the retardant accomplished by fuel types and attack strategy.

Secondly, research and chemical representatives have stated that a better definition of retardant requirement is needed; i.e., requirements for various fuel and fire conditions (George, 1982). Such information would permit the development of improved retardants and also provide more effective application. These statements question whether we really know what quantities of respective retardants are needed by fuel types, by fire behavior conditions, and by suppression strategies to effectively retard fire? Interviews and discussions with fire managers suggest that we do not.

Finally, the air tanker effectiveness is a function of configuration of the aircraft and the tank and gating system combined. In a letter dated June 15, 1982, to the air tanker industry, the Forest Service agreed that there was a

need to determine air tanker size and a process mechanism for aircraft replacement. Table 13 in Chapter IV of this report would indicate that air tankers and tanking systems vary both in cost and effectiveness in building retardant lines.

Conclusions (III)

1. Existing retardant system models are not widely accepted or understood.

2. Basic knowledge regarding effectiveness of applied retardants is lacking.

3. Management and research are not in agreement on retardant system research priorities.

IV. PROGRAM MANAGEMENT

Introduction

This chapter touches on several issues many of which have been raised elsewhere, but warrant further discussion. All tend to focus on management aspects of the air tanker program.

1. Contract Efficiency - Many discussions and concerns are currently centering around air tanker contracts. There are two main reasons for this. First, the air tanker industry has expressed dissatisfaction with the equity of current contracts. Second, the Forest Service has been scrutinizing the mix of all suppression tools to arrive at the most efficient and effective number of suppression units. This effort has been prompted by more austere budgets and the availability of new planning and analysis tools. In addition to the main reasons, all air tanker contracts are up for renewal at the end of the calendar year 1983.

Air tanker contracts are currently awarded on the basis of daily availability rates for specific availability period which are bid, and on fixed flight rates for each flight hour which is not bid, the latter are calculated based on cost. In addition, the contract provides for adjustments for changing fuel rates and adjustments in the daily availability for optional years of contract extention.

Air tanker contracts, over the years, have employed a number of contracting methodologies including: (1) fixed availability rates and bidding flight rates and (2) negotiated noncompetitive bid contracts. The terms and length of time have varied.

In recent years contracts have been offered through a single national contract with daily availability being bid and flight rates being fixed. The most recent contract was offered in a 3-year package with a 1-year guarantee and a 2-year option renewal. The contract provides for approximately 43 tankers during each of these years. This contract expires at the end of 1983.

The number of air tankers and the mandatory availability period has varied over the years for two reasons--amount of program dollars available, and a better understanding of actual air tanker needs. The number of air tankers and the varying mandatory availability period is of particular concern to the air tanker industry which is in business to make a profit.

Forest Service fire managers, facing a shrinking budget in terms of constant dollars since 1977, have begun to focus on high cost services. Aviation resources including air tankers and helicopters are among the items where fire managers are looking for opportunities to reduce costs. Some fire managers believe that contracting procedures that provide for: longer-term contracts, and incentives for improved performance, and air tanker reliability would reduce costs and improve effectiveness.

The Forest Service has agreed to consider developing a negotiated competitive bid system, instead of the current competitive bidding process. The Forest Service and industry have formed a joint task force to study the feasibility of such a new system (Siegel, 1982). The task force has developed a report which is currently under consideration. The revision of contract procedure provides an excellent opportunity to solve problems expressed by the Forest Service and contractors.

Needs can be expected to continue to undergo some change as management plans evolve and technology advances. Should the Forest Service become locked into long-term contracts without the above concerns and needs being adequately assessed, a less efficient and effective retardant system than is possible will result.

2. Air Tanker Efficiency - A number of fire managers and aviation personnel disagree concerning the selection of appropriate air tankers. One view is that platforms (aircraft) are of major importance, another view is that the type of tanking systems and number of gallons are more important. Still another view is that the combination of aircraft type and tanking system is the issue. These views are often manifested by a given Region expressing a preference for or against a particular type of air tanker.

A variety of factors should be considered in selecting the appropriate air tanker: vegetation fuel type, terrain, distance from base to fire, fire fighting tactics, frequency of use, alternative suppression tools, etc. These should be weighted against the performance characteristics of the individual aircraft (aircraft ground handling characteristics can also be a factor) and the tank and gate system in the plane. Most of these characteristics can be expressed as a production function (i.e., a ratio of inputs to outputs) in terms of individual aircraft.

A brief analysis comparing the capabilities of several air tankers is displayed in Table 13 to give emphasis to these statements. The table illustrates that the most appropriate aircraft is dependent on the desired suppression strategies

to be employed. For instance, the DC6 aircraft is the most expensive on a per-gallon bases for a 1-hour trip, yet it is the least expensive based on per mile of retardant line built. To select the optimum aircraft for a specific location a combination of aircraft capabilities, environmental characteristics and management needs must be considered.

Air Tanker Efficiency

Table 13

Aircraft type	Cost/gal /1 hr trip	rank	Cost/gal to 50 mi. target	rank	Cost/ drop	rank	Feet of Line/ drop 1/	rank	Cost/ mi. of line 2/	rank
PV2-RA	$1.76	6	$ .42	5	$420	1	315	8	$7140	9
B26-LY	1.72	5	.40	4	480	2	480	7	5280	6
B17-EV	1.64	2	.44	7	792	3	735	6	6336	8
C-119 HP	1.63	1	.42	5	840	6	900	4	5040	4
DC4 AU	1.64	2	.43	6	860	8	820	5	6020	7
PB4Y2-HP	1.65	3	.38	3	836	5	950	3	5016	3
DC6 SQ	1.77	7	.35	2	816	4	1290	1	4078	1
P2V BH	1.76	6	.35	2	858	7	900	4	5145	5
DC7 AU	1.69	4	.32	1	960	8	1090	2	4800	2

Source: Appendix J

Note:

1/ This column is a measure of aircraft effectiveness rather than efficiency. The distinction is discussed in Appendix I.

2/ Calculations are based on a coverage of 2 gpc. at a drop height of 200 ft.

A discussion of the effectiveness of air tankers is not included in this report because there is not sufficient data on which to evaluate it. In general, comments pertaining to Effectiveness of Applied Retardants (the previous

chapter) are germane to air tankers. Sufficient information from which to judge effectiveness is not available and warrants further consideration by A&FM and Research.

3. <u>Coordination with Industry</u> - The fire retardant industry includes the suppliers of retardant (currently three companies) and operators of contract air tankers (13 companies in 1981). Together they receive 73 percent of the retardant system expenditures or approximately $17.5 million annually.

As suppliers of a unique material and service, these companies have a unique relationship with the Forest Service. The Forest Service's objective is to utilize retardants when and to the extent that they are an efficient and effective tool. The industries objective is, of course, to maximize its return on investment. Both are concerned with a stable and healthy industry.

To minimize the opportunity for conflict, it is essential that good communication between industry and the Agency occurs. Comments received from these industries indicate a strong need to revitalize and to improve coordination and communication. Areas of identified concern included long-range Agency plans, estimates of current and future product use, product design, product satisfaction, and Agency and industry relations. Internal inputs expressed similar concerns with special interest for future needs.

4. <u>Inspection and Certification</u> - Air tankers are inspected and certified annually by an FAA licensed mechanic and by a Forest Service employee prior to the contract period. Boise Interagency Fire Center (BIFC) personnel indicate that air tankers are licensed as (1) restricted category aircraft or (2)

transport restricted category aircraft. These restricted category certificates are limited in scope and less rigorous than some other certification categories. Forest Service personnel feel that some of the FAA personnel view air tankers under contract to the Forest Service as "Public Aircraft" no longer bound by Federal Aviation regulations for civil aircraft. BIFC inspectors must therefore assume the FAA role to assure that air tankers meet airworthiness standards.

Many Forest Service A&FM personnel have expressed dissatisfaction with the current Forest Service air tanker inspection and certification program viewing it as inadequate and that requirements and standards are not strict enough to obtain satisfactory performance. Actual data to gauge the significance of the problem is limited. However, data expressing the relative degree of down-time is presented in Table 14. These data indicate that reliability does vary between contractors. A few contractors have a consistently higher percentage of down time.

Assuming the problem is a significant one, two options are available. One is to increase the aircraft maintenance standard as identified in the contracts and the frequency of inspection by qualified FS personnel. This option would require additional personnel and greater expenditures by the Forest Service.

The second option would be to devise a monetary bonus and/or penalty system to provide incentive for the operator to increase the reliability of the aircraft. This process would be written into the contract and only monitoring of down time would be necessary.

Contractor Nonavailability Percentage 1/

Table 14

Contractor	1978 % Unavailable	1979 % Unavailable	1980 % Unavailable	1981 % Unavailable
Lynch Air Tankers	.5	1.5	1.3	5.1
WAIG Aircraft Inc.	--	.2	1.1	.8
Aero Flite	--	2.1	1.1	1.6
Evergreen Helicopter	.4	3.6	1.5	3.0
Ralco	--	6.6	25.1	--
Central Air	2.3	6.8	2.5	5.4
Black Hills	.7	3.3	3.4	2.0
Aero Union	1.8	3.5	6.3	2.0
Hemet Valley	--	3.2	4.7	4.0
SIS-Q	.2	2.8	1.0	3.3
TBM, Inc.	.2	1.3	2.1	1.0
Douglas County	--	--	3.5	5.0
Trans-West	1.0	--	3.0	--
T&G	1.8	1.0	--	--
Hawkins & Powers	.1	2.2	2.5	9.4

Source: Appendix K

Notes: 1/ Nonavailability penalty as a percent of contract payment.

With both options the increased costs would be expected to be offset by reducing fire losses which result from unavailable aircraft. The second option has the advantage of not increasing Forest Service ceiling requirements.

5. Data Management - A considerable volume of data is collected and available for most components of the "Retardant Program System." In general, the problem is not the quantity of data but its quality. In almost every instance when a data set was checked against a second source there were significant irreconcilable differences. In some areas such as base operations, the general opinion of A&FM personnel was that there are no data.

Table 15 shows three seperate data sets for gallons of retardant. The first is the volume purchased, the second is the national accounting of total use, and the third is use records compiled by individual Regions.

An examination of this data suggest several possible problems. First, over a 5-year period, the Forest Service appears to have purchased 27 percent more retardant than it used. This may be a result of spillage, an uneven exchange with cooperators, or poor record keeping. Second, a check of regional records for Regions 1, 2, 4, and 5 suggest that an additional 13 percent less was used than is indicated by the national records. Third, the records further indicate that some Regions used more retardant than they purchased.

Inconsistent data on air tanker contract costs is also a problem. Three sets of records exist. The air tanker base initially tracks the actual days an aircraft is available and the amount of use it receives. These data get transmitted to the Forest where adjustments are often made prior to certification for payment.

Retardant Records

(Reported in Gallons)

Table 15

Region	FY	Retardant[1/] Purchased	Reported Use[2/] National	Reported Use[3/] Regional	Class D and Larger Fires Regional
R-1	77	552,636	37,400	360,240	190,695
	78	38,612	102,800	134,150	2,450
	79	935,708	993,165	868,105	276,570
	80	126,878	482,913	65,800	57,950
	81	767,506	747,750	693,900	95,450
Total		2,421,340	2,364,028	2,122,195	623,115
Ave. 5 Yr.		484,268	472,806	424,439	124,623
R-2	77	321,580	228,400	160,400	130,300
	78	295,813	154,900	140,300	104,300
	79	136,306	101,800	103,100	79,200
	80	246,176	333,104	210,100	115,400
	81	68,348	65,070	37,800	13,800
Total		1,068,223	883,274	651,700	443,000
Ave. 5 Yr.		213,645	176,655	130,340	88,600
R-3	77	2,430,409	2,104,587		723,842
	78	762,921	935,970		131,450
	79	2,243,493	2,367,303		1,039,684
	80	2,075,897	2,253,746		495,520
	81	1,349,639	1,491,628		232,000
Total		8,862,359	9,153,234		2,622,496
Ave. 5 Yr.		1,772,472	1,830,647		542,500
R-4	77	613,401	503,312	636,958	361,249
	78	600,422	390,537	618,851	345,065
	79	1,694,917	564,346	1,129,745	385,645
	80	725,592	354,948	464,583	226,880
	81	1,432,529	719,114	926,337	483,039
Total		5,066,861	2,532,257	3,776,474	1,801,878
Ave. 5 Yr.		1,013,372	506,451	755,295	360,376
R-5	77	8,781,798	5,078,501	5,318,630	
	78	6,514,557	3,023,432	1,600,420	
	79	10,226,137	6,366,533	5,037,728	
	80	9,346,080	4,576,851	4,700,348	
	81	8,355,199	5,848,111	3,433,871	
Total		43,223,771	24,893,428	20,090,997	
Ave. 5 Yr.		8,644,754	4,978,686	4,018,199	

Retardant Records

(Reported in Gallons)

Table 15 (Continued)

Region	FY	Retardant Purchased [1]	Reported Use National [2]	Reported Use Regional [3]	Class D and Larger Fires Regional
R-6	77	4,814,620	5,313,340		171,800
	78	1,312,165	1,304,048		130,050
	79	1,180,775	3,911,619		839,183
	80	1,289,181	1,635,707		112,860
	81	2,579,239	2,581,371		175,860
Total		11,175,980	14,746,085	(5,185,000) 1974-78	1,429,753
Ave. 5 Yr.		2,235,196	2,949,217	(1,037,000) Data	285,951
R-8	77	200,839	1,213,706		40,435
	78	459,865	497,459		76,565
	79	82,588	113,570		10,000
	80	254,005	611,460		175,400
	81	411,023	344,350		182,670
Total		1,408,320	2,780,545		485,070
Ave. 5 Yr.		281,664	556,109		97,014
R-9	77	426,000	77,345	80,295 (77,895)	2,400
	78	35,000	19,750	19,750 (19,750)	0
	79	26,000	58,750	58,750 (58,750)	0
	80	20,000	129,050	123,450 (86,450)	37,000
	81	6,950	15,650	15,650 (15,650)	0
Total		513,950 4/	300,545 5/	297,895 (258,495) 6/	39,400
Ave. 5 Yr.		102,790	60,109	59,579 (51,699)	7,880
R-10	77	876,174	0		
	78	655,074	10,000		
	79	606,271	0		
	80	296,566	18,000		
	81	869,972	0		
Total		3,295,057	28,000		
Ave. 5 Yr.		659,011	5,600		
National	77	18,807,618	14,556,591		
	78	10,674,428	6,438,896		
	79	19,509,304	14,477,086		
	80	14,380,375	10,395,779		
	81	15,840,405	11,813,044		
Total		79,212,130	57,681,396		
Ave. 5 Yr.		15,842,426	11,536,279		

Sources: 1/ General Services Administration 1977-1981.
2/ USDA Forest Service 1977-1981c.
3/ USDA Forest Service 1982e.

Notes: 4/ Mostly retardant (FIRE-TROL) used by Minnesota.
5/ Mostly water usage.
6/ Figures in parentheses represent amount of total which is water. Retardant figures included for D+ fires only.

Data are later compiled nationally at BIFC's contracting office and in the WO's A&FM Staff in terms of hours of use. (For special projects such as the recent Congressional request, a task force attempted to compile its own data.)

There is initially a planned use for a given year, the actual use data collected at the air tanker base (and often the most available) and the adjusted data set used for payment. (Adjustments are made for a variety of reasons such as, to correct for substitution of aircraft.)

A third example of data problems can be seen in Table 9 (Lead Planes In Service) supplied by WO, A&FM and Table 11 (Regional Lead Plane Efficiency). The latter was developed for this report from information received from individual Regions. The number of lead planes in the data set do not agree. In part, the discrepancy may be due to a difference in definition, but also it appears to relate to record keeping.

Another problem arises from the unavailability of data (e.g., aircraft data prior to 1978 is considered too incomplete to use.

Several reasons can be identified for why data problems exist. One is the number of offices involved in collection. For example, the air tanker data collection involves: the air tanker base, the forest offices, regional offices, BIFC contracting, and the WO's A&FM Staff. Another reason is that no attempt is made to maintain a single data base. Corrections and alterations are only fed into parts of the system. A primary reason for the condition of the data base seems to stem from the fact that it is not regularly used to tract and analyze the operation of the program.

Conclusions (IV)

1. The air tanker contract is a key element in acquiring and managing an efficient and effective air tanker fleet.

2. Air tanker efficiency and effectiveness is dependent on a host of characteristics involving the aircraft (and its tank and gate system), location, and tactical use.

3. The Forest Service role in assuring the airworthiness of air tankers and the extent of the problem is unclear.

4. Collection and management of data is disjointed and inadequate.

V. POLICY AND DIRECTION

1. Fire Management Policy - To understand the role and policy of the fire retardant program, it is necessary to understand current fire management policy. In 1977, fire management began to revise the basic policies under which the National Forest System viewed fire and the Agency's role in coping with it. The policy revision was preceded by a change in the name of the fire staff unit from Fire Control to Fire Management. As the name implies, the new policy takes a broader view seeing fire as an agent of the natural ecosystem with the potential to do good as well as harm. Thus, fire may be prescribed to accomplish management objectives when meeting a set of preestablished conditions. Wildfire suppression requires that special attention be given to a least cost approach which includes consideration of the cost, values at risk and alternative suppression options. On initial attack, this is accomplished primarily through a new presuppression planning system. For wildfires that escape initial attack, an on-the-spot analysis procedure called the "Escaped Fire Situation Analysis" has been developed to assess and determine the least cost strategy (FSM 5130.31). In all situations, regard for personnel safety remains a primary objective. The essence of the new policy is to scrutinize the economic implications of fire suppression in light of Forest Service resource goals and objectives.

The words efficiency (doing it quickly and simply) and effectiveness (doing what works) took on new meaning with the new policy. Efficiency became synonymous with least cost. Effectiveness became concerned with the cost to support various alternative resource management goals and objectives; i.e., how much of the goal can be accomplished at a given cost?

The Zero Code of the Fire Management portion of the Manual (FSM 5100) states that, "Fire management includes all activities for the protection of resources and other values from wildfire...." While aircraft and more specifically retardant aircraft have not been specifically mentioned in the new fire policy the intent is that aircraft as a suppression activity are to be evaluated along with all other suppression tools. Aircraft when planned for, or when used as a fire suppression tool for the protection of resources, are part of the regional responsibility to "provide a balanced fire management program which is cost efficient..." (FSM 5102).[5]

2. Aviation Policy - The aviation portion of FSM 5700 does not have a general Zero Code statement. This type of statement usually defines the functional program within the context of the overall Forest Service program goals. Such a statement would help to clarify the aviation role.

Several objectives are provided in FSM 5702 for aviation management. The first states that the overall mission of aviation management is "...to accomplish Forest Service programs effectively." (Generally speaking, aviation activities would not accomplish Forest Service programs but would provide support for their accomplishment.) The second objective is titled, "Mission Requirements." The first requirement is to have "efficient, economical, and safe aircraft services." These objectives and the statements made in the section titled, "Evaluations" in FSM 5719, reaffirm the need for determining the efficiency and effectiveness of aviation activities. Unfortunately, formal direction for accomplishing both is lacking in FSM 5700.

[5]Compound words such as cost efficient, cost effective, and economic efficiency are inappropriately used in FSM 5100 and other Forest Service literature in this

3. Retardant Use Policy - The policy and direction for the actual use of retardant is very sparce and informal with the exception of compliance with FAA regulations and other similar technical operational direction.

Direction on when to use retardants and how to judge their effectiveness is almost nonexistent. While Line Bosses and Air Attack Bosses are knowledgeable about retardant effectiveness, and generally do a good job, the decision process is often delegated to, or handled, by on-the-spot managers with very little guidance, criteria, or procedures from which to make decisions. The Fire Line Handbook (National Wildfire Coordinating Group, 1980) devotes one-half page to tactical-use criteria. These seven criteria have limited utility in that they do not suggest how the user is to judge effectiveness.

Some guidance can be gleaned from fire training courses but even in this area there is no emphasis on efficient or effective use. The air tanker guides developed by research can be useful but they are not a part of the formal training process or national direction. Experience appears to be the only significant guidance.

4. Fire and Aviation Planning - The FSM 5100 provides a general basis for establishing effectiveness criteria in support of resource management goals established in the land management planning process, (see FSM 5103.1 and 5121).

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reviewers opinion. The words efficiency or effectiveness should be substituted for the corresponding compound words, checking to see what it is they are measuring. In almost all cases efficiency is what is being dealt with. For a more complete discussion see Appendix L.

Beyond this point, the direction as it applies to aviation becomes less clear. FSM 5191, which is no longer current (but remains in the Manual) provided direction from which criteria could be established, though it was not founded on an economic rational. This direction was superseded by an interim directive on April 9, 1982, and was reissued as ID# 14 on March 25, 1983. Also portions of a handbook titled, "The Fire Management Analysis and Planning Handbook," FSH 5109.19, were issued in November 1982 and January 1983. The handbook presents the current planning process.

Unfortunately, Aerial Retardant Planning at the field level is, by in large, still based on the old direction found in the old FSM 5191. It is difficult to glean from the new direction just how aviation planning is to be revised and made responsive to the current planning process. This is not to imply that this is not possible nor desirable, but rather that the direction and process for aviation planning are unclear and to some extent incomplete.

Many forest managers will contend that fire management planning is very thorough, is second only to timber management in sophistication, and the system provides a true interface with the Forest Land Management Planning process. The Fire Management Analysis Planning System is indeed very structured and formal in its mechanical application and is capable of addressing and supporting resource objectives. However, as a planning and budgeting process it has been implemented by both formal and informal policy direction as it was being developed. This aspect of implementation and the degree of emphasis given fire planning in the different Regions has led to an "<u>uneven</u>" approach and varying results in forest land management plan drafts.

Some forest have done an excellent job in developing fire management alternatives for the forest plan based upon resource objectives and actual fire experience. Other have not been able to use or properly integrate the system into their plans. With the pressure to complete land management planning, revised fire planning (which is supposed to be an integral part of LMP) tends to be perceived as an additional burden, particularly on those Forests where land management plans are farther advanced. This has meant that fire planning is being handled in a rather cursory manner in many instances and becomes more of a process of justifying what we have had instead of a more in-depth analysis to determine how we might most efficiently and effectively complement LMP's.

Fire management planning is divided into four levels of planning. They are briefly described in Appendix M. From Levels I, II, or III, the forest's decision to have or not to have an air tanker available to support the LMP can be established. However, this does not establish the actual air tanker needs. They are shared resources and the decision requires input from several LMP's and the Washington Office. Other problems exist that also prevent arriving at an appropriate mix and number of aircraft. These have been discussed in Chapter IV.

Additional analyses are needed to establish appropriate numbers and types of air tankers. Also, other retardant support systems need evaluation to establish the number and location of support facilities and the appropriate retardant type to be used.

Several tools are available to conduct these additional analyses and have been used by individual Regions, but direction to perform these analyses and select

the appropriate analytical tools is lacking. Also, the tools themselves have not been fully developed or tested. However, in many instances they are currently capable of producing better information for decisions than can be accomplished without their use.

Only when the retardant system analyses have been completed and fire plans are an integral part of land management plans can it be said that the most efficient and effective retardant operation has been identified to support the accomplishment of resource management objectives.

Conclusions

1. Fire Management policy as stated in FSM 5100 encompasses aviation policy considering it as an activity for the suppression of wildfire.

2. Aviation policy lacks direction on how to accomplish an efficient and effective program.

3. Aviation and Fire Management planning and analysis procedures do not require an in-depth analyses of retardant system needs.

4. Direction for effective application of retardants is very minimal.

REFERENCES

Anderson, Norman and T. Pickett 1981 — "Fire Retardant Value Analysis Guides." USDA Forest Service, Washington, DC.

Bjornsen, Robert L. 1968 — "Air Tanker Use--A 5-Year Study." Fire Control Notes, Vol. 29, No. 4. USDA Forest Service, Washington, DC.

Chandler, Craig and H. DeBruen 1976 — Memorandum to Director of Intermountain Research Station. Subject: Proposed Cooperative Program. USDA Forest Service, Washington, DC. (July 23)

Council of Economic Advisers 1983 — "Economic Report of the President" and "The Annual Report of the Council of Economic Advisers, United States Government Printing Office, Washington DC.

Gale, Robert D. 1977 — "Evaluation of Fire Management Activities on National Forests." Ph.D. Dissertation Michigan State University, East Lansing, MI.

General Services Administration 1977-1981 — "Contract Summary Form GSA 1584, Denver, CO.

George, Charles W. 1982a — Memorandum to Region 2, Director of Aviation and Fire Management, USDA Forest Service, Missoula, MN. (July 29)

__________ 1982b — Memorandum to Richard Montague, Assistant Director, Aviation and Fire Management Staff, USDA Forest Service, Washington, DC.

Grigel, Joseph 1982 — Telephone conversation with Joseph Grigel. Chemonics Industries. (September 23)

Hafterson, John A 1983 — Memorandum to Regional Foresters and Area Director from the Acting Director, Aviation and Fire Management Staff, USDA Forest Service, Washington, DC. (March 10)

Hardy, Charles E. 1974 — "Alberta Fire Retardant Effectiveness Evaluation Study." Report summarizing work under contract No. OSW 4-0120, USDA Forest Service. (December)

Hardy, Charles E. 1976 — Chemicals for Forest Fire Fighting. National Fire Protection Association, Boston, MA.

Headley, Roy 1916 — Fire Suppression District 5. USDA Forest Service.

Hirsch, Ernest and Gideon Schwarzbart 1980 — DEPLOY*TANKER--A User's Guide. USDA Forest Service, Management Sciences Staff, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

Hirsch, Ernest 1982 — "Output Data Relating to Air Tankers." An unpublished personal communique, from Pacific Southwest Station to the Policy Analysis Staff, Berkeley, CA.

Hirsch, Charles J. and Roland N. McKean 1965 — The Economics of Defense in the Nuclear Age. Harvard University Press, Atheneum reprint, New York.

Hodgson B.S. and E. C. Little 1978 — "Air Tanker Evaluation in Three Canadian Provinces." Forest Fire Research Institute, Ottawa, ONT.

Marty, Robert J. 1974 — Study Materials Natural Resources Administration 450, Michigan State University, East Lansing, MI.

National Wildfire Coordinating Group 1980 — Fireline Handbook No. 3, Chapter 50, Section 53.1, Washington, DC.

Petersen, Don L. 1982a — "Past, Present & Future of Wildland Retardants." Monsanto Industrial Chemical Company, Ontario, CA.

——— 1982b — Retardant Use and Practices. Monsanto Industrial Chemical Company, Ontario, CA.

Peterson, R. Max 1982 — Memorandum and report to Honorable Jim Weaver, Chairman, Subcommittee on Forest, Family Farms, and Energy Committee on Agriculture, House of Representatives, Washington, DC. (June 15)

Philpot, Charles W. — Memorandum to Robert D. Gale from the Director of Forest Fire and Atmospheric Sciences Research Staff. USDA Forest Service, Washington, DC. (October 5)

Scherer, Frederic M. 1965 — "Government Research and Development Programs" Proceeding from Measuring Benefits of Government Investments, edited by Robert Dorfman, Brookings Institute, New York.

Scott, Robert H. 1973 — The Pricing System. Holden-Day Inc., San Francisco, CA.

Siegel, Robert D. 1982 — Memorandum to John F. O'Neal, Representative of Air Tanker Industry, from Deputy Assistant Secretary of Agriculture, Washington, DC. (October 26)

Simard, Allan J. 1979 — "A Computer Simulation Model of Forest Fire Suppression with Air Tankers." Canadian Journal of Forest Research, Volume 9, No. 3, Ottawa, ONT. pp. 390-398.

Stein, Jess, Ed. 1980 — Random House College Dictionary. Random House Incorporated, New York.

Swanson and Helvig 1974 — "Extended High Altitude Retardant Drop Mechanization Study." Honeywell Corporation.

Weaver, Robert W. 1982 — "Evaluation of Short-Term Retardants." California Department of Forestry, Sacramento, CA. (February 1)

West, Allan J. 1982a — Memorandum to Regional Foresters and Area Directors, 5160 Equipment and Supplies. USDA Forest Service, Washington, DC. (March 30)

________ 1982b — Memorandum to Regional Foresters and Fire Management Directors. 5190 Management, Washington, DC. (July)

Wilson Carl C. 1980 — <u>A Critical Analysis of the Aerial Application of Fire Retardants in Forest Fires Suppression.</u> Vols. 1 and 2. Chemonics Industries, Phoenix, AZ.

U.S. Congress 1982 — <u>Federal Regisger Rules and Regulations</u>, 36 CFR Part 219, Federal Register, Vol. 47, No. 190, p. 43026. (September 30.)

USDA Forest Service 1972 — <u>National Fire Planning -- Instruction.</u> (Draft) Washington, DC.

USDA Forest Service 1976 — "Forest Service Aviation Study." Aviation and Fire Management and Staff Report. Washington, DC.

________ 1977a — "Forest Service Aviation Study for Leadplanes" Aviation and Fire Management Staff. Washington, DC.

________ 1977b — "Focus Users Guide," Pacific Southwest Forest and Range Experiment Station. Riverside, CA.

________ 1977-1981a — Large Fire Report -- Summaries 1977-1981. Form 5100-11. BIFC Contracting. Boise, ID.

________ 1977-1981b — "National Forest Fire Report," Aviation and Fire Management Staff. Washington, DC.

________ 1977-1981c — Retardant Use Report, 5700-10 Aviation and Fire Management. Washington, DC.

________ 1978-1981 — "Air Tanker Helicopter and Large Tanker Information," BIFC Contracting Staff. Boise, ID.

________ 1979a — "Fire Management Budget Study." Policy Analysis Staff Report, Washington, DC.

________ 1979b — <u>Air Tanker Performance Gudies.</u> Intermountain Forest and Range Experiment Station, Ogden, UT.

__________ 1982a *Fire Management Analysis and Planning Handbook*, FSH 5109.19 Chapters 30 and 40. Washington, DC. (November)

__________ 1982b Data provided by Aviation and Fire Management Staff, Washington, DC.

__________ 1982c *Fire Management*, FSM 5100, Washington, DC.

__________ 1982d *Aviation Management*, FSM 1957, Washington. DC.

__________ 1982e Memorandums submitted by each Region providing data and answers to specific requests. (August)

__________ 1982f "Air Tanker Study Statistical Computation 1977-1981," Branch of Logistics Support, BIFC, Boise, ID.

__________ 1982g *Planning*, FSM 1900, Washington, DC.

__________ 1983a "Air Tanker Statistics (1977-1983)", BIFC Contracting Staff, Boise, ID.

__________ 1983b *Fire Management Analysis and Planning Handbook*, FSH 5109.19, Chapter 10, Washington, DC. (January)

APPENDICES

APPENDIX A

Fire Activity Index 1/

Year	R-1	R-2	R-3	R-4	R-5	R-6	R-8	R-9	R-10	NFS
1960	5.2	5.7	10.7	11.8	40.5	19.5	7.2	1.9	.01	11.5
1961	9.5	.5	4.7	9.2	16.1	6.6	1.6	1.3	.00	5.5
1962	2.1	2.4	5.1	4.0	18.7	2.7	5.3	4.0	.01	4.8
1963	1.4	2.4	2.1	3.1	4.7	1.6	12.3	3.9	.01	3.6
1964	1.5	2.8	4.9	7.2	24.2	3.6	5.1	3.3	.00	5.9
1965	.1	2.3	3.5	.4	4.7	1.2	3.1	2.8	.00	2.0
1966	8.4	3.6	9.4	15.0	34.1	4.8	5.7	1.7	.01	9.3
1967	12.9	.7	9.8	.4	8.3	7.7	5.0	.9	.02	5.2
1968	3.1	1.4	9.8	3.9	26.4	9.8	4.4	2.0	.03	6.6
1969	.7	1.6	6.2	.4	7.2	2.3	2.2	1.3	.12	2.5
1970	6.9	2.0	10.9	3.4	37.5	22.6	8.6	1.3	.01	10.7
1971	1.4	.8	10.5	3.0	10.4	2.5	6.3	3.5	.01	4.3
1972	2.4	1.8	9.2	6.8	22.0	3.7	3.2	2.6	.01	5.5
1973	7.8	.7	3.3	3.5	14.6	3.2	.6	.3	.01	3.8
1974	3.2	4.0	21.8	6.5	22.7	3.6	4.1	1.5	.02	7.5
1975	.0	2.2	5.1	.4	18.8	1.2	2.6	1.2	.00	3.4
1976	1.4	1.8	10.6	4.4	15.2	2.9	8.3	4.7	.00	5.5
1977	1.3	2.0	4.1	3.3	39.0	3.4	4.8	1.0	.00	6.5
1978	1.1	2.7	6.4	4.1	19.4	3.3	8.9	1.0	.02	5.1
1979	2.9	.7	15.3	16.9	22.8	5.6	2.4	.6	.00	7.3
1980	2.2	4.4	12.6	5.3	34.3	2.1	11.4	5.4	.15	8.6
1981	3.2	0.1	1.2	13.8	14.4	2.4	14.8	2.2	.00	5.8
1982	.0	.1	.3	.2	.7	.1	.4	.1	.00	2.2
Mean	3.4	2.0	7.7	5.5	19.9	5.0	5.6	2.1	.02	5.8
Standard Deviation	3.4	1.4	5.0	4.8	11.5	5.5	3.8	1.4	.03	2.5
Coefficient of Variaion	101%	71%	65%	88%	58%	110%	67%	69%	150%	43%

1/ For explanation of procedure see Gale, 1977.

APPENDIX B

Retardant Use Since 1959

(M Gallons)

Year	BLM	Agency CDF	USFS	Total
		Thousands of gallons		
1959	--	566	3,249	3,815
1960	--	590	5,928	6,518
1961	124	876	7,658	8,658
1962	297	1,635	3,414	5,346
1963	351	1,480	3,518	5,349
1964	--	3,352	5,368	8,720
1965	184	2,2441	1,955	4,580
1966	999	3,313	5,942	10,254
1967	588	53,263	7,754	11,605
1968	1,195	4,009	5,748	10,952
1969	2,308	3,413	5,255	10,976
1970	2,050	4,165	10,658	16,873
1971	3,088	2,267	9,825	15,180
1972	3,397	3,286	9,429	16,112
1973	3,736	4,690	15,958	24,384
1974	4,110	6,778	14,744	25,632
1975	--	--	--	--
1976	--	--	--	--
1977	--	--	13,686	--
1978	--	--	7,001	--
1979	--	--	14,655	--
1980	--	--	11,555	--
1981	--	--	11,886	--

Source: USDA Forest Service, 1982b.

APPENDIX C

Retardant Use by Base

(Gallons)

FS & Cooperator

	1977	1978	1979	1980	1981	Type	Average
R-1							
Missoula	123,882	11,262	371,666	41,284	452,788	P	200,176
Coeur d'Alene	143,450	20,150	213,550	6,750	59,750	F	88,730
Helena	61,941	-	46,925	41,284	48,356	P	39,701
Kalespell	37,540	-	138,898	-	158,256	P	66,939
W. Yellowstone	61,941	-	41,294	41,294	48,356	P	38,577
Region	428,754	31,412	812,333	130,612	767,506		434,123
R-2							
Grand Junction	197,065	159,545	41,294	76,957	3,754	P	95,724
Jeffco	41,191	41,294	37,540	85,588	41,294	P	49,381
Cody	51,760	37,700	33,600	30,800	23,300	F	35,432
Region	290,016	238,539	112,434	193,345	68,348		180,537
R-3							
Winslow	409,514	196,834	263,709	186,639	188,097	P	248,958
Grand Canyon	468,550	39,300	145,000	97,550	68,550	F	163,790
Albuquerque	N/A	N/A	26,605	150,000	162,190	F	67,759
Alamogordo	116,374	78,834	54,433	82,588	45,048	P	75,455
Libby	207,055	18,000	-	68,000	198,000	F	98,211
Prescott	253,235	-	488,000	218,050	96,250	F	211,107
Silver City	152,037	120,128	41,294	153,426	246,876	P	142,752
Coolidge	213,750	106,460	1,075,785	877,144	255,128	F	505,654
Region	1,820,515	559,556	2,094,826	1,833,397	1,260,139		1,513,686
R-4							
Boise	13,139	206,470	551,738	161,626	544,413	P	295,477
Dixie(Cedar City)	60,064	-	41,294	41,294	52,752	P	39,081
McCall	73,203	77,203	146,406	82,588	248,201	P	125,520
Salt Lake City	144,529	41,294	85,588	217,732	173,272	P	132,483
Region	290,935	324,967	825,026	503,240	1,018,638		592,561

R-5							
Chester	850,281	82,588	123,882	315,336	376,772	P	349,772
Fox	366,018	330,352	1,001,786	919,730	488,081	P	621,193
Fresno/CDF	207,221	285,182	618,368	866,227	453,821	P	486,164
Goleta	275,919	118,251	309,705	320,967	269,320	P	258,832
Hemit(Ryan)/CDF	609,969	1,283,840	2,038,737	2,087,953	1,022,488	P	1,408,597
Paso Robles/CDF	987,396	252,268	857,264	262,602	738,440	P	619,594
Porterville/CDF	637,280	176,673	580,990	488,470	529,169	P	482,516
Ramona/CDF	378,403	929,950	908,909	783,328	635,145	P	727,147
Redding/CDF	1,135,000	464,790	300,000	623,782	780,700	F	660,855
Rohnerville/CDF	220,829	153,952	204,480	424,220	105,504	P	221,797
Willows-Closed'81	166,000	174,092	176,931	100,700	118,100	F	147,164
Stockton- " "	747,985	86,342	389,046	218,445	422,837	P	372,931
Region	6,582,301	4,338,280	7,510,098	7,411,760	5,940,377		6,356,563
R-6							
Wenatchee	981,100	150,000	499,200	153,928	201,205	F	397,087
LaGrande	279,600	117,500	760,060	76,345	237,454	F	294,192
Redmond	673,000	165,050	853,850	273,562	357,545	F	464,601
Everett	205,500	115,000	61,100	35,000	38,400	F	91,000
Medford	1,062,100	278,500	411,000	411,581	624,708	F	557,578
Klamath Falls	593,580	212,290	413,952	237,936	962,646	O	484,081
Troutdate	275,600	-	218,600	68,375	39,381	F	120,388
Region	4,070,480	1,038,340	3,217,762	1,256,727	2,461,339		2,408,927
R-8							
Asheville	13,139	163,299	-	22,524	74,732	P	54,739
Tallahassee	-	22,524	-	-	26,841	P	9,873
Deland	41,294	-	9,385	-	101,108	P	30,357
Weyers Cave	7,508	13,139	-	-	-		4,129
Fort Smith	82,588	-	41,294	75,080	-		39,792
Knoxville	28,155	152,037	-	53,166	96,712	P	66,014
Tri-Cities	28,155	108,866	31,909	20,647	70,336	P	51,983
Region	200,839	459,865	82,588	171,417	369,729		256,887

Notes: P = Phoschek - Registered trademark product of the Monsanto Company
F = Fire trol - Registered trademark product of Chemonics (a subsidiary of Dowel Chemical)
O = OMEGA - supplied by Omega Co.

Source: Peterson, 1982.

APPENDIX D

Approved Retardants

AERIAL APPLICATION

Retardants	Mix Ratio
Fire-Trol GTS	1.76 lbs/gal
Fire-Trol 100	2.78 lbs/gal
Fire-Trol 931-L (11-37-0)	4:1
1/ Phos-Chek 259F (DAP)	1.14 lbs/gal
Phos-Chek AF (MAP)	.96 lbs/gal
Phos-Chek GW (MAP)	.96 lbs/gal
Phos-Chek GF (MAP)	.96 lbs/gal
2/ Megatard 2700	1 gal sulphate + .06 lbs thickener/gal

GROUND

Retardants	Mix Ratio
Fire-Trol 934-L (11-37-0)	4:1
Fire-Trol 936-L (11-37-0)	4:1
Phos-Chek GW (MAP)	.96 lbs/gal
Phos-Chek GWX (MAP)	.96 lbs/gal
Phos-Chek GF (MAP)	.96 lbs/gal

Approved Wetting Agents

Fire Chem - Available GSA Stock No. 6850-01-111-2200

KRC - KRC-Portland, Oregon

Source: West, 1982

Notes: 1/ Phos-Chek 259F only retardant approved for fixed-tank helicopter use.
2/ Approved for contract base only.

APPENDIX E

Tons/Gallons/Price Conversion

Gallons/Ton

Monsanto 1/

1977 - 1980: 1 ton = 1,869 gallons
1981: 1 ton = 2,203 gallons

Chemonics 2/

Fire Trol 100: 1 ton = 860 gallons
Fire Trol 931: 1 ton = 850 gallons

Prices

National Averages
to f.o.b. Designations 3/

Monsanto

	1977	1978	1979	1980	1981
Per Gallon	$0.464	0.495	0.502	0.552	0.662
Per Ton	$866.67	925.69	937.70	1,032.58	1,458.39

Chemonics Industries

	1977	1978	1979	1980	1981
Per Gallon	$0.424	0.445	0.465	0.580	0.652
Per Ton	$362.14	380.13	397.65	495.56	557.77

Sources: 1/ Peterson, 1982
2/ Grigel, 1982
3/ General Services Administration, 1977-1981

Base Operation Costs by Bases

Region	Base Name	Total Base Investment Cost	Average Annual Investment Cost	Annual Main Cost	Annual Operating Cost	Total Annual Base Cost
1	Missoula	30,700	2,046	250	5,332	7,628
	Coeur d'Alene	61,820	4,122	500	5,873	10,495
	Helena	28,803	1,920	445	10,400	12,765
	Kalispell	94,095	6,274	431	5,798	12,503
	W. Yellowstone	82,000	5,466	250	5,313	11,029
	TOTALS	297,418	19,828	1,876	32,716	54,420
2	Cody	31,100	2,064	420	1,000	3,494
	Rapid City	12,000	800	300	2,480	3,580
	Laramie	15,000	1,000	0	2,500	3,500
	Jeffco	230,000	15,334	4,380	10,203	29,917
	TOTALS	288,100	19,208	5,100	16,183	40,491
3	Winslow	71,860	4,790	1,500	89,200	95,490
	Grand Canyon	269,000	17,934	500	109,033	127,467
	Albuquerque	7,315	488	1,000	100,825	102,313
	Alamagordo	250,000	16,666	2,500	72,800	91,966
	Libby	30,000	2,000	500	86,000	88,500
	Precott	67,678	4,512	200	112,749	117,461
	Silver City	925,200	61,680	6,000	45,000	112,680
	Coolidge	9,270	618	1,300	90,610	92,528
	TOTALS	1,630,323	108,688	13,500	706,217	828,405
4	Boise	125,000	8,334	2,500	37,186	48,020
	*Dixie 1/	35,104	2,340	3,787	4,000	10,127
	McCall	85,000	5,666	1,500	13,327	20,493
	Salt Lake	0	0	2,000	8,000	10,000
	TOTALS	245,104	16,340	9,787	62,513	88,640
5 2/	Chester	400,000	26,666	6,000	24,000	56,666
	Chico	500,000	33,334	3,000	15,000	51,334
	Fox	1,200,000	80,000	15,000	33,000	128,000
	Fresno (Joint CDF-FS)	15,000	1,000	2,000	90,000	93,000
	Goleta	95,000	6,334	3,000	42,500	51,834
	Hemet (Ryan) CDF-FS Base	50,000 (FS Share)	3,334	None	70,000 (FS Share)	73,334
Closed 1977	Ontario	10,000	666	8,000	30,600	39,266
	Paso Robles	CDF-owned operated base; pay retardant cost/aircraft			2,000	2,000
	Porterville	500,000	33,334	4,000	37,000	74,334
	Ramona	43,300	2,886	2,000	46,400	51,286
	Redding	600,000	40,000	11,500	20,300	71,800
	Stockton	Contract owned	0	Pay only a cost of retardant pumped to aircraft; see letter Stanislaus R-5 package.		
	Willows	50,000	3,334	2,500	10,000	15,834
	Norton	0	0	0	2,600	2,600
	TOTALS	3,463,300	230,888	57,000	423,400	711,288

1/ This base transferred to BLM in 1982 along with equipment. No base costs have been charged to FS in FY 82 or expected in future years.

2/ Cooperator costs are not included in this data.

2/ Cooperator costs are not included in this data.

Base Operation Costs by Bases

Region	Base Name	Total Base Investment Cost	Average Annual Investment Cost	Annual Main Cost	Annual Operating Cost	Total Annual Base Cost
6	Wenatchee	26,000	1,734	1,000	73,000	75,734
	La Grande	65,000	4,334	3,000	33,000	40,334
	Redmond	46,000	3,066	1,000	28,000	32,066
	Everett	28,000	1,866	2,000	19,000	22,866
	Medford	100,000	6,666	10,000	45,000	61,666
	Klamath Falls	40,200	2,680	10,800	7,300	20,780
	Troutdale	800,000	53,334	0	22,900	76,234
	TOTALS	1,105,200	73,680	27,800	228,200	329,680
8	Asheville, NC	40,000	2,666	500	13,000	16,166
	Tallahassee, FL	5,250	350	800	3,600	4,750
	Deland, FL	72,555	4,838	1,600	6,150	12,588
	Weyers Cave	3,000	200	500	4,485	5,185
	Fort Smith, AR	30,000	2,000	1,000	18,000	21,000
	Knoxville, TN	299,780	19,986	1,000	15,100	36,086
	Tri-Cities, TN	133,640	8,910	1,850	15,700	26,460
	TOTALS	584,225	38,950	7,250	76,035	122,235
9 3/	NO Forest Service Bases	Share cost on airplanes - offset agreement				
	TOTALS	0	0	0	0	0
10 3/	No Forest Service Bases	Plan to contribute $30,000/year starting in FY 1982				
	TOTALS	—	—	—	—	—

3/ Regions 9 and 10 rely on cooperators - no base costs are incurred

APPENDIX G
Table a

Air Tanker Cost Data

(Availability)

Region	1978	1979	1980	1981
1	$ 309,459	$ 203,416	$ 201,103	$ 194,988
2	100,891	70,949	69,564	127,854
3	565,859	506,565	527,394	812,485
4	292,657	113,338	174,172	185,447
5	718,647	663,788	689,659	894,850
6	1,090,061	1,167,839	1,137,799	1,080,360
8	247,912	165,321	215,848	226,700
9	49,350	33,579	36,830	42,542
10	0	0	0	0
Total	$3,374,836	$2,924,795	$3,052,369	$3,565,226

Source: USDA Forest Service, 1983a

Notes: Components of Totals Above
- mandated period part is planned costs
- pre and post parts are actual costs
- includes all premandated and postperiod availability

APPENDIX G
Table b

Air Tanker Cost Data

(Flight Cost)

Region	1978	1979	1980	1981
1	$ 135,228	$ 367,261	$ 398,382	$ 444,958
2	82,240	109,347	137,505	173,912
3	291,017	829,844	1,085,351	1,210,639
4	221,915	296,660	257,886	308,077
5	1,063,000	2,073,000	2,418,069	2,561,174
6	534,488	1,779,200	1,194,016	2,041,178
8	169,035	89,227	284,865	306,969
9	13,260	14,167	55,105	14,881
10	0	0	0	0
Totals	$2,510,183	$5,558,706	$5,831,179	$7,061,788

Source: USDA Forest Service, 1983a

Lead Plane Data (Use and Costs)
(Regional Summary)
5-year period 1977-1981

Region	FY	Number and Type Aircraft	Total Hours Flown	Lead Plane Hours/FS Aircraft	Hourly Use Rate FS Aircraft	Hourly FOR Rate FS Aircraft	Total L.P. Cost FS Aircraft	Lead Plane Hours-Lease/ Contract	Lead Plane Cost-Hrs for Lease/Contract	Total L.P. Cost-Lease/ Contract	Total L.P. Hours	Total L.P. Cost	Avg. / Hr. Cost-L.P.
1	77	(2) B58 E55	364	-0-	---	---	---	300	135	40,500	300	40,500	135
	78	(2) 58TC	205	-0-	---	---	---	129	203	26,190	129	26,190	203
	79	(3) P. Baron	615	139	88	171	36,000	298	203	60,495	437	96,495	221
	80	(3) P. Baron	553	67	132	91	14,940	228	252	57,455	395	72,395	183
	81	(2) P. Baron	419	274	162	90	69,050	-0-	---	---	274	69,050	252
2	77	(2) Queen Air P. Baron	779	49	94	73	8,185	-0-	---	---	49	8,185	167
	78	" "	748	58	89	77	9,630	-0-	---	---	58	9,630	166
	79	" "	753	9	159	85	2,195	-0-	---	---	9	2,195	244
	80	" "	760	62	102	85	11,595	-0-	---	---	62	11,595	187
	81	" "	569	93	123	158	26,135	-0-	---	---	93	26,135	281
3	77	(2) BE58TC (1) BE58	259	-0-	---	---	---	208	264	54,910	208	54,910	264
	78	(2) BE58TC	333	-0-	---	---	---	198	204	40,390	198	40,390	204
	79	(1) BE58P (2) BE58TC	665	118	80	63	16,875	118	81	9,560	236	26,435	112
	80	(2) BE58P (2) BE58TC	757	169	128	61	31,940	59	66	3,895	228	35,835	157
	81	(4) BE58P	956	240	144	73	52,080	68	172	11,695	308	63,775	207
4	77	(2) Cessna 310	1,236	33	68	167	7,755	-0-	---	---	33	7,755	235
	78	(2) Cessna 310	1,059	49	68	110	8,720	-0-	---	---	49	8,720	178
	79	(1) Cessna 310 (1) Baron 58P	1,442	124	68	114	22,570	-0-	---	---	124	22,570	182
	80	(2) Baron 58P (1) Cessna 310	1,262	92	116	238	32,570	-0-	---	---	92	32,570	354
	81	(2) Baron 58P	962	184	145	121	48,945	-0-	---	---	184	48,945	266

Region	FY	Number and Type Aircraft	Total Hours Flown	Lead Plane Hours/FS Aircraft	Hourly Use Rate FS Aircraft	Hourly FOR Rate FS Aircraft	Total L.P. Cost FS Aircraft	Lead Plane Hours-Lease/ Contract	Lead Plane Cost-Hrs for Lease/Contract	Total L.P. Cost-Lease/ Contract	Total L.P. Hours	Total L.P. Cost	Avg. / Hr. Cost-L.P.
5	77	(6) Barons	1,615	89	73	38	9,880	419	207	86,735	508	96,615	190
	78	(6) Barons	1,503	27	81	25	2,860	101	216	21,815	128	24,675	193
	79	(6) Barons	2,682	326	89	75	53,465	301	181	54,480	627	107,945	172
	80	(6) Barons	2,438	262	141	85	59,210	211	177	37,345	473	96,555	204
	81	(6) Barons	2,174	219	144	81	49,275	-0-	---	---	219	49,275	225
6	77	(1) Baron (1) Aero Cmdr. (6) Cessna 310	1,256	217	69	87	33,850	187	110	20,570	404	54,420	135
	78	(5) Cessna 310	1,805	-0-	---	---	---	210	122	25,620	210	25,620	122
	79	(4) Cessna 310 (1) Baron 58P	1,459	56	88	87	9,800	171	136	23,255	227	33,055	146
	80	(2) Baron 58P (1) Aero Cmdr. (3) Cessna 310	1,841	165	150	87	39,105	168	145	24,360	333	63,465	191
	81	(2) Baron 58P (1) Aero Cmdr. (2) Cessna 310	1,321	197	180	143	64,220	189	195	36,855	386	101,075	262
8	77	(1) Aero Cmdr. (1) Cessna 310	418	55	61	198	14,245	-0-	---	---	55	14,245	259
	78	(2) Aero Cmdr.	355	39	70	153	8,695	-0-	---	---	39	8,695	223
	79	(1) Aero Cmdr. (1) Baron 58P	303	49	100	165	12,985	-0-	---	---	49	12,985	265
	80	(1) Aero Cmdr. (1) Baron 58P	457	162	100	156	41,470	-0-	---	---	162	41,470	256
	81	(1) Aero Cmdr. (2) Baron 58P	430	133	150	283	57,590	-0-	---	---	133	57,590	433
9	77	(1) Aero Cmdr.	322	-0-	---	---	---	-0-	---	---	-0-	---	---
	78	(1) Aero Cmdr.	535	-0-	---	---	---	-0-	---	---	-0-	---	---
	79	(1) Aero Cmdr.	413	-0-	---	---	---	-0-	---	---	-0-	---	---
	80	(1) Baron	311	-0-	---	---	---	-0-	---	---	-0-	---	---
	81	(1) Baron (1) Aero Cmdr.	429	28	164	107	7,590	-0-	---	---	28	7,590	271
10	77 - 81	NONE											

Source: USDA Forest Service, 1982e

APPENDIX I

OUTPUT DATA RELATING TO AIRTANKERS

I. FROM FOCUS PROGRAM

A. OUTPUT FROM SUPPRESSION MODULE

1. Provides details of use of available airtankers (or helicopters used as airtankers) whenever the fire parameters and constraints specified by the user demand aerial retardant delivery.
2. Details of air tankers use consist of complete flight schedules and retardant delivery data.
3. Location (Geographic Coordinates), time (date and clock time) and characteristics of all fires are required input data.
4. Simulation will continue for each fire until fire is contained or escapes. Fire is deemed to escape when fire spread rate (according to the simulation model) exceeds the ability to construct line with the available resources.

B. OUTPUT FROM SMOKEY 2

1. Provides cost details on air tanker use for any or all fires selected by user.
2. Costs are broken down into variable costs (flight costs, retardant costs, etc.), fixed costs (e.g. availability), one-time costs (e.g. runway repair).
3. Cost and aircraft use data may be summarized for yearly operation for an entire forest.

II. FROM DEPLOY * TANKER PROGRAM

A. STANDARD OUTPUTS

1. Summary of input data: characteristics and location of tankers used; available airfields; extent of geographic area covered; control parameters specific to current deployment alternative. (Table 6)

2. Retardant delivery potential to all geographic units (gallons as a function of time); fraction of coverage of units after one hour (by % volume and % area, relative to required amount specified by user for each geographic subdivision). (Table 9)

3. Extent of retardant coverage for areas in different volume requirement and land value classes (by % of area fully protected after one hour). (Tabel 11)

B. OPTIONAL OUTPUTS

1. Geographic details for all units: unit locations relative to airfields; size of units and unit substructures in various retardant requirement and land value classes; location of units within national forests. (Tables 1 - 5)

2. Retardant delivery potential (gallons as a function of time) during simultaneous multiple fires on multiple geographic units - (number of fires and units subject to user selection). (Table 6.1)

3. Detailed retardant delivery chronology (time, volume delivered, identity of air tanker) for any geographic unit (units selected by user). (Table 7)

4. Earliest tanker arrival time for all units. (Table 8)

5. Extent of retardant coverage for areas in different volume requirement and land value classes, by individual forests. (Table 12 - same data as Table 11 substructured by forests.)

6. Measure of area within given volume ranges of retardant delivery potential as function of time. (Tables 13 and 14)

7. Delivery details of retardant volumes as function of time, and of delivering aircraft by selected volume requirement and land value classes in selected forests (Tables 15 and 16).

8. Average yearly retardant requirements, identification and use of aircraft and pro-rated cost of delivery for each geographic unit (Table 17).

9. Average yearly aircraft and airfield use, and retardant delivery (Table 18).

III. SOME COMPARISONS AND COMMENTS

A. REGARDING COST OUTPUTS

1. FOCUS gives detailed and precise cost elements to the extent that the program output provides an accurate simulation of the tactical operations applied to each fire. Variable costs of retardant at different locations are accounted for, as are availability costs and flight costs for tankers and fixed costs associated with retardant delivery operation.

2. DEPLOY * TANKER provides only one cost item: the average annual flight cost for retardant delivery for each tanker. It also calculates average number of gallons delivered by each aircraft. Retardant and availability costs must be added by user.

B. GENERAL PURPOSE IN PROGRAM DESIGN

1. FOCUS emphasizes the indivudal forest as the planning unit and covers all fire-fighting activities.

2. DEPLOY * TANKER looks only at retardant delivery capabilities but on a wide geographic scale.

3. DEPLOY * TANKER does provide at the user's option detailed localized ouptut but its principal purpose is to investigate the effects of additions, deletions, changes in type and in the location of airtankers on a region-wide basis.

4. The two programs address different problems in aviation and fire management.

C. STRENGTHS AND WEAKNESSES IN OUTPUTS

1. FOCUS - perhaps FOCUS' greatest strength, namely the attention to detail, may be its greatest weakness also since all details of each fire simulated need to be specified. The program does provide an accurate description of the initial phases of suppression but, because of rigid rules inherent in computer programs, ceases to provide information when a fire is deemed to have

escaped. In my estimation the information obtained relating to airtankers is insufficient for planning purposes.

2. DEPLOY * TANKER - this program does not pay attention to small details, but emphasizes data pertaining to large areas at the expense of some accuracy. Cost and retardant use are based on ten-year averages (not on a fire by fire basis). The emphasis is on retardant delivery capability as a planning concept. The aim is providing adequate protection for all areas under Forest Service management. Retardant requirements were obtained from individual forests and, as I was told, were based for the most part on the 1972 fire plan with some updated thinking.

D. SOME THOUGHTS APART OF FOCUS AND DEPLOY * TANKER

1. I think both programs provide useful input to A&FM. However, it seems, before we can really make any benefit/cost assessments, we have to take some hard looks at the value of protection in terms of what is gained in vegetation, water resources, wildlife, private property, etc., as opposed to the cost of protection. We would have to do some probabilistic work in this area. I think it's a hard job and would take quite a few people with extensive expertise in varying subject matters. But there is an enormous national investment involved and the payoff is proportionately great.

2. I'd be glad to talk to you more if your are interested in greater detail on DEPLOY * TANKER, I am an expert on that - but I am very much a tyro on FOCUS.

ERNIE HIRSCH

Principal O. R. Analyst

Management Sciences Staff

(FIS-449-3215)

Source: Hirsch, Ernest, 1982.

Air Tanker

(1-Hour Trip Cost) 1/

Aircraft 2/ Type	Capacity (Gallons)	Average Availability Rates/Day 1981	Average Availability Rates/Hour Based on 8-Hr. Day	Flight Rates Per Hour 1981	Retardant Costs/ Trip Based on $1.00/Gallon	Total Cost Per 1-Hr. Trip	Cost/Gal./ 1-Hr. Trip
PV2 RH	1,050	618	77	726	$ 1,050	$ 1,853	$ 1.76
B-26 LY	1,200	672	84	778	1,200	2,062	1.72
B-17 EV	1,800	569	71	1,076	1,800	2,947	1.64
C-119 HP	2,000	522	65	1,196	2,000	3,261	1.63
DC-4 AU	2,000	697	87	1,196	2,000	3,283	1.64
PB4Y2 HP	2,200	775	97	1,326	2,200	3,623	1.65
DC-6 SQ	2,450	1,101	138	1,753	2,450	4,341	1.77
P2V BH	2,450	815	102	1,753	2,450	4,305	1.76
DC-7 AU	3,000	1,057	132	1,944	3,000	5,076	1.69

Source: USDA Forest Service, 1983a and 1978-1981.

Notes: 1/ Cost to deliver a gallon of retardant by aircraft type for 1981 for 1-hour trip (includes cost of retardant and air tanker costs).

2/ The last two letters identifies the specific contractor and aircraft.

APPENDIX J

Air Tanker

(50-Mile Target Cost) 1/

Aircraft Type	Capacity (Gallons)	Cost/Gallon Per 1-Hr. Trip	Average Aircraft Speed 2/ Miles/Hour/Payload	Adjustment Factor For 50-Mile Target	Cost/Gallon for 50-Mile Target
PV2	1,050	$ 1.76	207	.24	$ 0.42
B-26	1,200	1.72	219	.23	0.40
B-17	1,800	1.64	182	.27	0.44
C-119	2,000	1.63	196	.26	0.42
DC-4	2,000	1.64	196	.26	0.43
PB4Y2	2,200	1.65	219	.32	0.38
DC-6	2,450	1.77	248	.20	0.35
P2V	2,450	1.76	248	.20	0.35
DC-7	3,000	1.69	265	.19	0.32
				(50 - 3)	

Source: Compiled from Appendix J, Table a.

Notes: 1/ Cost comparison to deliver a gallon of retardant by aircraft type to 50-mile target based on 1981 data.
2/ Speed of aircraft based on full payload; round trip to target including take-offs and landings.

Air Tanker

(1-Mile Line Cost)1/

NATIONAL

Aircraft Type	Capacity (Gallons)	Cost/Gallon for 50-Mile Target	Line Length2/ Per Drop	1-Drop Initial Attack Mission (Gallons)	Cost for 1-Drop Initial Attack Mission	Build 1 Mile of Fire Line (Gallons)	Cost for 1-Mile Line
PV2 RA	1,000	$ 0.42	315'	1,000	$ 420	17,000	7,140
B-26 LY	1,200	0.40	480'	1,200	480	13,200	5,280
B-17 EV	1,800	0.44	735'	1,800	792	14,400	6,336
C-119 HP	2,000	0.42	900'	2,000	840	12,000	5,040
DC-4 AU	2,000	0.43	820'	2,000	860	14,000	6,020
PB4Y2 HP	2,200	0.38	950'	2,200	836	13,200	5,016
DC-6 SQ	2,450	0.35	1,290'	2,330	816	11,650	4,078
P2V BH	2,450	0.35	900'	2,450	858	14,700	5,145
DC-7 AU	3,000	0.32	1,090'	3,000	960	15,000	4,800

Source: Computed from Appendix J, Tables a and b and USDA Forest Service, 1979

Notes: 1/ Cost comparison for air tankers for line construction and initial missions to a 50-mile target.
2/ 2GPC at 200 ft. drop height, water-like retardant.

APPENDIX K

Air Tanker Contract Data

Contractor	1978		1979		1980		1981	
	Total Available	Total Unavailable	Total Available	Total Unavailable	Total Available	Total Unavailable	Total Available	Total Unavailable
Lynch Airtankers	$222,469	$1,159	$164,019	$2,489	$209,171	$2,652	221,530	11,207
WAIG Aircraft Inc.	*	*	54,610	86	78,536	843	85,875	671
Aero Flite	*	*	47,512	998	51,712	588	79,102	1,252
Evergreen Helicopter	53,500	222	132,716	4,798	107,353	1,566	167,603	5,016
Ralco	47,788	0	75,595	5,020	72,775	18,240	*	*
Central Air	125,136	2,890	183,100	12,446	144,378	3,555	436,700	23,719
Black Hills	60,288	425	397,771	13,132	390,589	13,205	429,229	8,648
Aero Union	506,505	9,168	119,547	4,215	65,322	4,134	69,552	1,360
Hemet Valley	*	*	241,115	7,665	250,727	11,766	242,476	9,693
SIS-Q	891,943	1,512	544,710	15,477	538,484	5,146	358,350	11,676
TBM, Inc.	516,416	1,263	427,597	5,453	453,304	9,605	475,676	4,711
Douglas County	*	*	*	*	383,215	13,488	638,845	32,185
Trans-West	222,990	2,154	*	*	139,610	4,188	*	*
T&G	455,880	8,067	476,433	47,499	*	*	*	*
Hawkins & Powers	290,492	152	139,236	3,065	128,040	3,248	422,854	39,769

Source: USDA Forest Service, 1982f

Notes: 1/ Nonavailability penality as a percent of contract payment.
2/ A * indicates no contracts were awarded.

APPENDIX L

A TREATISE ON EFFICIENCY AND EFFECTIVENESS

Confusion exists between the meaning of the words efficiency and effectiveness as currently used by the Forest Service. As defined in the dictionary, their meaning is separate and distinct. Efficiency is "...an accomplishment of, or ability to accomplish, a job with a minimum expenditure of time and effort...." (Cost may be used as a unit of measure instead of time or effort.) Effectiveness is "producing the intended or expected result," (Stein 1980). With efficiency the emphasis is on measuring input used to accomplish the task. With effectiveness the emphasis is on output, how much of the task was accomplished.

Marty (1980) has explained it similarly. Evaluation of efficiency attempts to determine how much time, money, or effort was expended in carrying out a given activity. And evaluation of effectiveness examines an activity in relation to how much or how well a stated objective was accomplished.

Current Forest Service literature such as FSM 1900, FSM 1970, the Section 6 Regulation, and several research and administrative documents have compounded these words with others to form such terms as cost effectiveness, cost efficiency, and economic efficiency. The usages of these compounds is inconsistent and unclear. For instance, in FSM 1900, 3 CFR 219, and Section 6, cost effective is defined as, "achieving specified outputs or objectives under given conditions for the least cost (i.e., inputs)." Effectiveness cost is also defined with the same words.

<u>Efficiency, economic</u> is defined in FSM 1970 as:

> "The usefulness of inputs (costs) to produce outputs (benefits) and effects when all costs and benefits that can be identified and valued are included in the computations. Economic efficiency is usually measured using present net value, though use of benefit-cost ratios and rates-of-return may sometimes be appropriate."

<u>Cost efficiency</u> is defined simarily (U.S. Congress 1982).

Examination of how these terms are applied in practice reveals that no matter which terms are used, efficiency--or how to accomplish a job with minimum input--is almost always what is measured. For example, FSM 1971.7--Computing Measures of Economic Efficiency states:

> "The principal measure of economic efficiency in Forest Service evaluations is present net value.... In addition to the above measures...may use cost-effective analyses (see FSM 1971.81)."

<u>Least Cost Analyses, FSM 1971.81</u>

> "Evaluations seeking to determine the most effective means of attaining specific results may simply determine the relative costs of each alternative. Determining the value of the specified goal is not necessary."

A review of the current standard economic literature including such authors as Heilbroner, Friedman, Musgraves, and Scott reveals that the term <u>effectiveness</u> is not used and efficiency is used only in the context of optimizing the allocation of resources in the sence of "Pareto Optamality." This is a concept that has limited application because of an inability to measure changes in individual utility and societies insistance on constraining the process (Scott 1973).

None of the standard economic literature reviewed uses compound terms such as cost effectiveness or cost efficiency. Cost efficiency appears to be a term unique to the Forest Service and cost effectiveness is a term that is not widely used outside the Forest Service but has it roots in the Department of Defense analyses literature that states:

> "...cost-effectiveness technique used fairly extensively in military weapon systems program analysis. The cost-effectiveness approach itself is straightforward. By means of some decision-making process which may defy rational calculation, it is stipulated that certain definite, tangible objectives are to be attained.... Given the objective, the costs of various alternative programs for achieving it are compared...minimizing the cost of achieving the specified objective.... Now there are many kinds of decisions which cannot be resolved adequately through the cost-effectiveness approach. It is useless for determining whether an objective is worth achieving. For instance, a minimum-cost program for detecting all submarines within 200 miles of the United States coast may be identified by cost-effectiveness analysis, but the analysis says nothing about whether the effort is in fact worthwhile." (Scherer 1965)

Fire Management has further expanded the definition of the terms efficiency and effectiveness by defining processes to be used in their measurement. A modification of the least cost concept (Headley 1916) has become a standard process for analyzing fire plans and budgets. The modified process termed "cost plus net loss" allows for the added consideration of benefits or positive results from fire. It was suggested to be used as a test for measuring the effectiveness of program alternatives (Gale 1977). However, whether you are efficiency or effectiveness depends on how you have stated the problem to be analyzed.

> "In fact the only way to know what such a ratio really means (or sum if we subtract rather than divide benefits by cost) is to tighten the

constraint until either a single budget (program cost or input) or particular degree of effectiveness is specified. And at that juncture, the ratio reduces itself to the test of maximum effectiveness for a given budget, or a specified effectiveness at a minimum cost... (efficiency)," (Hitch and McKean 1965).

Generally speaking, economic analysis has concerned itself with efficiency. (This explains the lack of reference to effectiveness in the literature.) the goal or output is a given or fixed quantity defined somewhere else in the social system. Thus, we hear economists referring to their job as being one of allocating limited resources (or dollar inputs).

However, we can fix the input and try to get the most output from a given input. In Chapter 10, Section 11.2 of the recently published (FSM 5109.19) handbook referring to budget analysis, the following statement appears:

> "The budget analysis process identifies the most efficient unit distribution of fire protection funds at any given national or Regional budget level...."

Any time the budget level is a given, the analysis will be measuring effectiveness not efficiency.

To fully understand the results, we can not vary input and output simlutaneously. What is important is not that we must always use economics to analyze both sides of the equation, but that we are able to understand what we have analyzed and in turn the results. Fire management should be using economics to analyze both efficiency and effectiveness to avoid problems encountered in the past; i.e., efficiently accomplishing the wrong goals (Gale 1977).

The main point of this discussion is that terms shold not be posed or used if they are contrary to the standard literature or useage unless we are willing to state so when they are used. The fact that a small group of individuals may have agreed to their definition does little to improve communication unless we assume that the purpose of defining them was for technocrats to talk with other technocrats.

Most readers or listerners will rely on their common understanding of terms or consult standard references if they are so inclined. For example, if the words cost effective analysis has been preformed they will concluded that effectiveness has been analyzed in terms of cost--not efficiency.

Appendix M

Planning Level Summary

The bulk of the current fire planning process is described in the Fire Management Analysis and Planning Handbook (FSH 5109.19), part of which is incomplete. This process offers the user four levels of fire planning (see Figure 3). Each (beginning with Level I) requires a higher level of detail and more in-depth analysis than the previous level. Levels I and II are patterned after the 1980 fire budgeting process and are the most commonly used alternative process.

Level I simply compiles the current cost of fire protection along with historical fire history and weather data. The fire protection cost would include a display of retardant operations cost.

For selected Forests, generally where the fire job is more complex, a Level II analysis would be conducted. This level requires the formulation of alternative mixes of protection forces. Resources such as air tankers may be added to or dropped from the protection force. The analysis process produces a least cost alternative along with a means of comparing alternative protection programs.

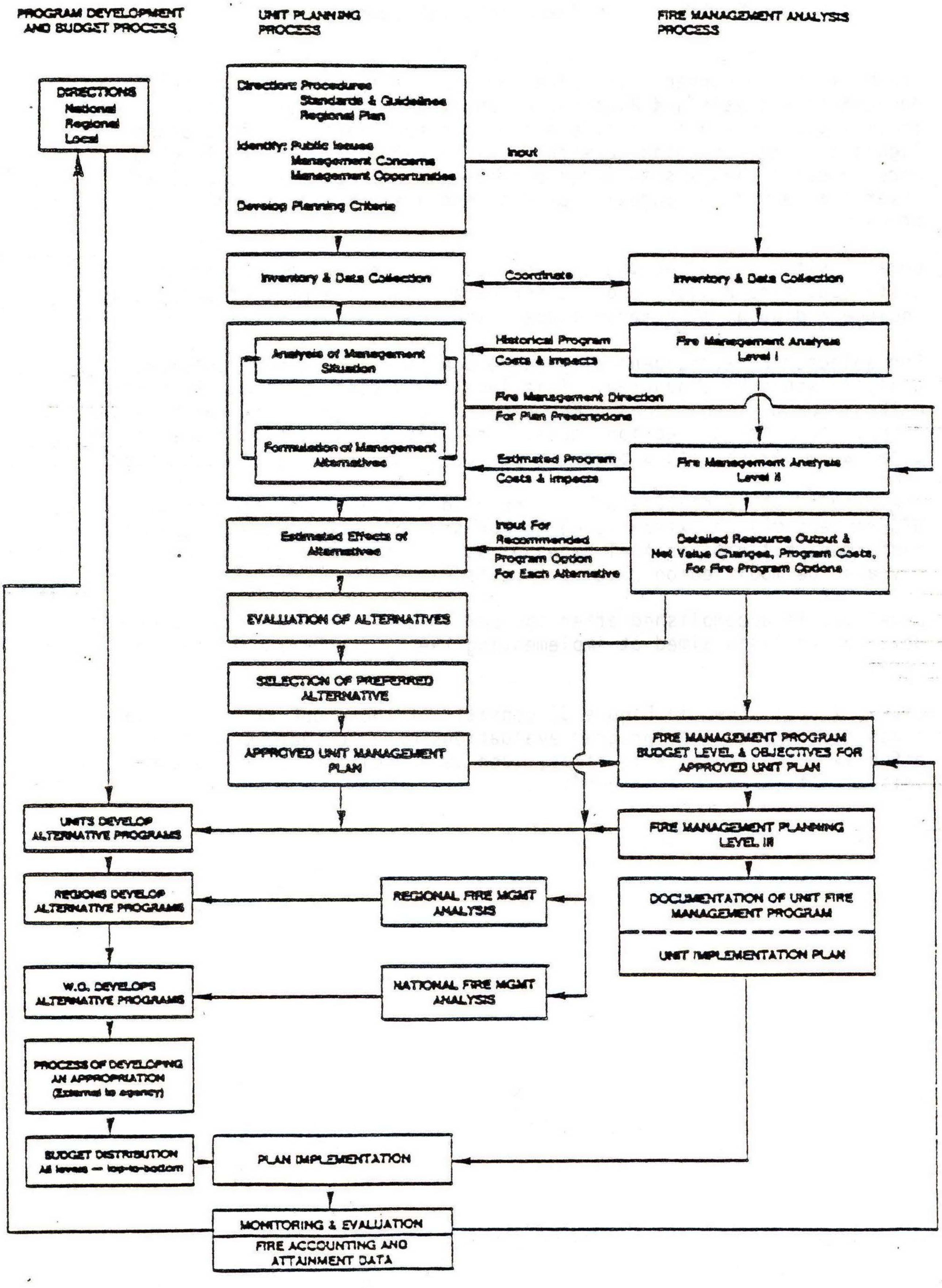
The results of Level II analysis are used to select the appropriate protection program and may be extrapolated to Forests where only Level I analysis was performed, but similar fuel types exist. In this manner, protection programs may also be modified on Level I forests.

Level III is accomplished after the LMP is approved and consists of additional detailed analysis aimed at implementing the fire program within the given budget level.

Level IV (not shown in Figure 3) consists of those operational (usually conducted on the spot) program evaluations made to support efficient and effective operational activities, such as a decision to use an air tanker on initial attack or on a large fire.

Figure 3

FIRE MANAGEMENT ANALYSIS INTERFACE WITH UNIT AND PROGRAM PLANNING



Number of Fires and Air Tanker Use (average for 1977-1981)

APPENDIX N

Region	Class A Total / Air	Class B Total / Air	Class C Total / Air	Class D Total / Air	Class E Total / Air	Class F Total / Air	Class G Total / Air	All Fires Total / Air
1	801 / 5 0.6%	214 / 16 7.4%	32 / 12 35.9%	4 / 1 25.0%	4 / 1 25.0%	2 / 0 10.0%	0 / 0 0.0%	1,057 / 20 1.9%
2	519 / 1 0.2%	173 / 1 1.2%	27 / 1 5.2%	4 / 0 5.0%	3 / 0 6.7%	2 / 0 20.0%	0 / 0 0.0%	728 / 7 0.9%
3	1,811 / 10 0.5%	505 / 34 6.7%	81 / 16 19.8%	12 / 2 16.7%	7 / 2 22.9%	4 / 1 25.0%	1 / 0 60.0%	2,421 / 65 2.7%
4	875 / 4 0.5%	177 / 12 6.8%	32 / 3 9.4%	9 / 1 8.9%	7 / 1 11.4%	3 / 1 20.0%	3 / 0 6.7%	1,611 / 22 1.9%
5	1,801 / 11 0.6%	408 / 28 6.8%	71 / 10 14.6%	21 / 2 9.5%	15 / 2 12.0%	11 / 1 7.3%	6 / 1 17%	2,333 / 55 2.3%
6	1,368 / 16 1.1%	229 / 22 9.4%	23 / 4 18.3%	7 / 1 17.1%	3 / 1 20.0%	2 / 1 20.0%	0 / 0 0%	1,632 / 44 2.7%
8	537 / 2 0.3%	1,284 / 26 2.0%	450 / 13 2.9%	44 / 3 5.9%	12 / 1 5.0%	4 / 0 10.0%	0 / 0 0%	2,331 / 44 1.9%
9	232 / 5 2.2%	437 / 5 1.2%	121 / 1 0.5%	10 / 0 0.0%	2 / 0 0.0%	1 / 0 20.0%	0 / 0 0%	803 / 11 1.4%
10	19 / 0 1.1%	3 / 0 0.0%	1 / 0 0.0%	0 / 0 0.0%	0 / 0 0.0%	0 / 0 0.0%	0 / 0 0.0%	23 / 0 0.1%
Totals	7,962 / 53 0.7%	3,429 / 146 4.3%	838 / 60 7.2%	110 / 8 7.0%	54 / 7 12.2%	29 / 4 13.8%	11 / 1 9.1%	12,443 / 267 2.1%

Summary Totals	A, B, and C Fires	D, E, F, and G Fires
	12,229 / 259 2.1%	94 / 12 12.3%

Source: Hafterson, 1982

Notes: 1/ Total = Average number of fires
Air = Average number of fires which had air tankers as initial attack or first reinforcement

2/ Totals may not compute because of rounding

United States Department of Agriculture

Forest Service

WO

Reply to: 4050 Research Programs

Date: October 5, 1983

Subject: Review of manuscript entitled An Evaluation of Fire Retardant Use

To: Robert Gale, PA

Here are our comments and suggested additions to your policy analysis report on fire retardants. I have enclosed our working copy because it contains editorial and other minor changes.

We recommend that research and development be excluded from your fire retardant system components. We suggest material on page 31 and be added to Section III. We think the status of this important research could be better described by including the following funding level trends.

	$ INT-RWU 2107
FY82	473K
FY83	406K
FY84	218K

The FY84 funding will reduce the project to one scientist with limited technical support and operating funds.

We would also recommend that major attainments and knowledge gaps be added to the R&D section.

- o Airtanker performance information developed for 90% of the fleet.
- o Developed tank design guide.
- o Improvement of airtanker contract to include performance criteria.
- o Contract research with private industry to develop knowledge about high attitude drop characteristics, performance models, ETAGS Tank and model development, corrosion studies and theology studies. All of this research has been used to improve retardant delivery and effectiveness.
- o Determined impact of retardant chemicals on streams.
- o Participated in field evaluations of several retardants.
- o Help develop design and participated in field operational studies of retardant effectiveness.
- o Developed technical basis for MAFFS and H-MAFFS.
- o Developed user guides for corrosion protection.

Robert Gale, PA

- o Currently studying effectiveness in altering combustion in both direct and indirect attack.

The major knowledge gaps in retardant system design and management are as follows:

- o Retardant effectiveness under field conditions.
- o A better understanding of rheology and the distribution of retardant through the fuel bed.
- o Development of a method to specify tank and gating design from desired drop pattern and apply it to currently available aircraft.
- o Refine design criteria for helitankers to the level available for fixed wing aircraft.
- o Development of additional user guides to improve ability to interpolate current information to all regions and conditions.
- o Improve tactics and strategies for ground application.
- o Develop information for assessing short-term retardants and additives.

We would also suggest inclusion of a discussion about the various ways in which retardant chemical could be purchased. For example, it would be possible to specify the performance of the components (retardant, corrosion, spoilage inhibitor, thickner and dye) making up a retardant and allow chemical companies to bid on providing a "generic" product. Estimates of 1/3 current costs have been arrived at by adding up component costs. Reducing costs from $750/ton to $250/ton may be possible. We think it is important to include this discussion in your analysis so that FS can display the pros and cons of all procurement options.

Let me or Ben Lyon know if you need any help in finishing your important report.

R. R. Sommers / for

CHARLES W. PHILPOT
Director of Forest Fire and
Atmospheric Sciences Research

Enclosure